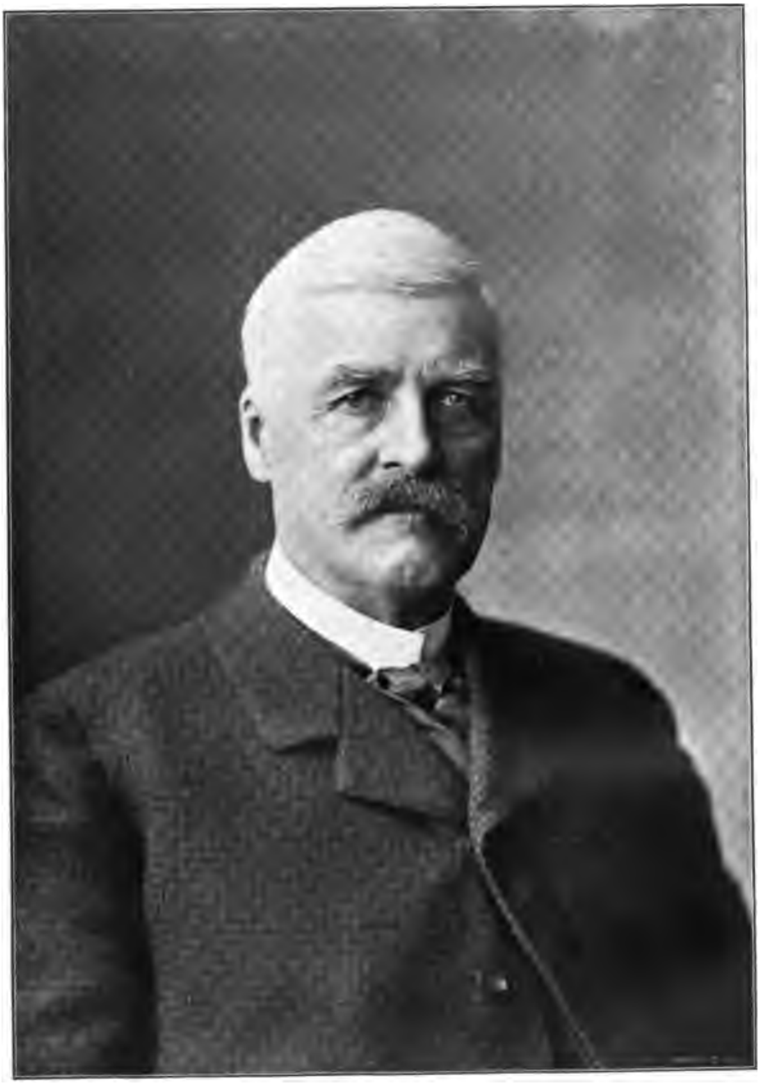
1901-1902

ELEVENTH
BIENNIAL REPORT
OF THE
STATE ENGINEER
COLORADO



E. S. NETTLETON.

STATE ENGINEER 1883 TO 1886.
BORN 1832; DIED APRIL 22, 1901.

Eleventh Biennial Report

of

The State Engineer

to the

Governor *of* Colorado

for the

Years 1901 & 1902

Denver, Colorado
The Smith-Brooks Printing Co., State Printers
1902

LETTER OF TRANSMITTAL.

NOVEMBER 30, 1902.

TO HIS EXCELLENCY,

JAMES B. ORMAN,

GOVERNOR OF COLORADO.

SIR: IN COMPLIANCE WITH THE PROVISIONS OF LAW, I HAVE THE HONOR TO TRANSMIT HEREWITH THE ELEVENTH BIENNIAL REPORT OF THE TRANSACTIONS OF THE DEPARTMENT OF THE STATE ENGINEER FOR THE TWO FISCAL YEARS ENDING NOVEMBER 30, 1902.

VERY RESPECTFULLY,

YOUR OBEDIENT SERVANT,

ADDISON J. McCUNE,

STATE ENGINEER.

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INTRODUCTORY REMARKS AND REVIEW OF THE WORK OF THE DEPARTMENT FOR 1901 AND 1902.

A review of the work of this Department will show a steady growth in irrigation development. While no large systems have been inaugurated and completed during the period, it will be seen that there has been a gradual filling in, so to speak, under the present systems. The greatest development has been, perhaps, in the inter-mountain country in the way of construction of small ditches and reservoirs. In many of the older districts small ditches, using seepage, flood and waste waters, have been constructed. As the farming of the land has become more intensive, so, also, one might say that the use of the water is more intensive. Small enterprises heretofore neglected have been taken up. Reservoir construction has progressed quite rapidly since the last report, and several notable dams have been completed or are nearing completion. The Denver Union Water Company, at Cheesman lake, has about completed what is to be one of the great dams of the world. The Fossil Creek reservoir, owned by the North Poudre Canal Company, in Larimer county, has been completed, and is notable on account of its height, it being an earth-filled dam, and from the fact that it will depend almost entirely upon flood and seepage waters. The Douglas reservoir, also in Larimer county, is another important acquisition to the same system. Jackson and Sanborn lakes, and others of the Bijou Canal Company, between Greeley and Fort Morgan, will be supplied principally by seepage and flood waters in the Platte. The Castlewood dam, on Cherry creek, has also been repaired and the reservoir is now being filled.

The number of ditches reported by the commissioners as being in operation is 4,067. Several districts have no commissioner, so from them no reports were obtained, but they are known to have many ditches and considerable irrigation. From the best information obtainable there are over 4,500 ditches and canals now in operation. One canal (the Fort

Lyon) is operated for a distance of 113 miles. There are fifty canals over fifty miles in length, and fifty-one canals over twenty miles in length. An effort was made to procure definite data concerning the number of reservoirs in the state and their capacity, but without result. It is positively known, however, that there are over five hundred in operation, ranging in area from two thousand acres to five acres, and with capacities of from 90,000 acre feet to 50 acre feet. For the same reason that we were unable to get the total number of ditches and reservoirs, we were unable to get the total number of acres under ditch or under cultivation. The estimated acreage under ditch is 3,000,000, and the estimated acreage actually cultivated, 2,100,000.

The eastern, western and northwestern parts of the state are discussed in a special chapter by Mr. John E. Field, Deputy State Engineer, in another part of this report.

The work of stream measurements and other investigations of the water resources has been extended somewhat, in co-operation with the United States Geological Survey. This work is given in detail in another chapter in the report of Mr. A. L. Fellows, resident hydrographer of the United States Geological Survey. The comparative tables of stream measurements are omitted in this report, as they were published in the last biennial report, and have since been put into bulletin form by Mr. Fellows, together with a large amount of other valuable information upon the water resources of the state, and are published by the interior department. They can be had upon application to this office, or to the bureau of publications at Washington, D. C.

Especial attention is called to the remarks upon the subject of a larger co-operation with the geological survey, under the head of "Recommendations," and to the remarks of Mr. Fellows in his report upon the same subject; also, upon the matter of permanent gaging stations for some of our most important streams.

We are especially pleased to announce that surveys are being made on three large enterprises by the United States geological survey, and it is confidently expected that construction on some one or two of them will be begun in the spring of 1903. The three enterprises are the Pawnee, in the northeastern part of the state; the Gunnison tunnel, near Montrose, and the Highline canal, in Grand valley, which it is proposed to carry into Utah.

This Department, through Mr. Elwood Mead, Chief of Irrigation Investigations, department of agriculture, obtained a report from Mr. C. G. Elliott, drainage expert, upon drainage and seepage, which appears in another chapter, and which, it is believed, will be instructive. Attention is called to the recommendation of Mr. Elliott on the need of a drainage law. A notice of the work of co-operation with this Department will be found under the head of "Recommendations."

The reports of the various officers reveal the fact that the interest in irrigation is increasing rapidly, and that the people are studying the subject in a manner that will result in much good. Considerable thinking and planning have been done along the line of consolidation of interests in each drainage system. This was strongly recommended in the last report of this office. The most important move in this direction has been made in the Clear Creek district, where a strong committee is now actively engaged in working out a plan for forming an association of all the ditch and reservoir owners in that drainage. Some form of irrigation law was recommended in the last report as a means of consolidation. The Thirteenth General Assembly enacted such a law, but it has not yet been tested by practice. It is believed in districts where it is desired to raise money to increase the water supply, or to improve the systems already built, that organization under this law will be more convenient than any other form of association. The state of California was the first to enact the irrigation district law. Experience with it there developed some defects, but an entirely new statute was adopted in 1897, remedying the obnoxious features of the original law, and making especial provision for the consolidation of separate ditch and reservoir interests. This fact emphasizes the value of the municipal direction and control of irrigation, as recognized by the present needs of California, and should largely influence the policy of Colorado in that particular.

The constantly increasing number of requests coming to this office for information on all matters connected with irrigation shows a growing interest in the subject and a desire on the part of the people for instruction, especially in our own state. The special demand is for irrigation laws and for information upon the measurement of water. For this reason it is thought best to re-print in this report a large part of "Bulletin No. 1, on Water Measurements," and also a short digest of the irrigation laws.

The Thirteenth General Assembly appropriated $500 per year for the use of this office for traveling expenses. Fortunately transportation was furnished this office and its deputies in almost every instance. The five hundred dollar expense fund enabled us to do considerable additional work in investigation and in ditch gaging. In many cases the ditch owner bore the per diem of the deputy and in other cases paid his expenses. With the aid of the railroads and the ditch owners $500 was about sufficient, but this office should have greater independence and freedom of movement and not be compelled to depend on the ditch owners to pay any part of the expenses. It is hard, to say the least, to rate a man's ditch, accept his hospitality, put him to trouble and expense, and then take the water away from him on which he depends for the money necessary to pay these same expenss. Five hundred dollars for two persons traveling for a year, when they cover from 40,000 to 50,000 miles, is not sufficient, especially as there are many things which were left undone during the last two years which should have been done and which would be of benefit to the state in general and to irrigators in particular.

This office has been supplied with additional book cases and now has a library of considerable value. It has not as yet been indexed, through lack of funds. An index of the books and of the subjects should be made and would cost probably from $100 to $150. The library contains the reports of the agricultural department, its year books, the reports of the United States Geological Survey, State Engineers' reports from numerous states, journals of engineering societies and has in bound form bulletins and reports on Hawaii, Alaska, Porto Rico, Canada and Englond, in reference to irrigation and agriculture. There are also in the library the Farmers' Agricultural Bulletins of the agricultural department and the agricultural colleges of Wyoming and Colorado. Works on good roads and forestry have also a place in the library and many valuable bulletins and pamphlets on these subjects are available for reference. An especial effort should be made to keep a complete set of all the bulletins published by the government and by the different states with reference to all of the subjects mentioned above. From time to time standard books of reference, with the best available information on engineering subjects, should be added to the library, which would be available, not only to the employes of this office, but to the public in general. Matters regarding the possibility, resources, growth and development of different parts of the

state should also be kept. Much valuable information is often contained in the folders of different railways, pamphlets from chambers of commerce, etc. It has been found that many tourists, especially those who are traversing the state by means of wagon and team, come to this office for information such as is contained in these pamphlets.

The office has also been supplied with a dark room for the developing and printing of photographs. Photography enters so largely at the present day into scientific investigation that this feature of the office should be maintained and made of use. The office now has numerous photographs of some of the most interesting, important and instructive parts of the state. This collection should be added to from time to time. Photographs taken during the progress of work are especially desirable, and should be preserved in this office.

Owing to lack of funds but little attempt has ever been made by this Department to collect data of the precipitation, as provided by law, and nothing whatever has been done for the last twelve years. In Mr. Fellows' report to this office will be found a summary of the data furnished by Mr. Brandenburg, section director of the United States Weather Bureau, for the years 1900 and 1901, which will be of interest.

Seepage measurements on the South Platte were continued during each fall of the last biennial period. Through the courtesy of Prof. Carpenter we are able, also, to publish the results of his work on the Uncompahgre and Cache la Poudre rivers, and the Big and Little Thompson, St. Vrain, Clear and Bear creeks, for the same period.

The following bulletins have been issued from this office during the last two years:

Denver, Colo., May 3, 1901.

Commissioner District No.——————

Dear Sir—The irrigation season being at hand, your attention is called to the following points:

In the mountains there appears to be an average amount of snow which, although falling somewhat later than desirable, will probably last well with favorable conditions in the spring. The precipitation for the year being generally considerably below the normal, we may expect rains to be more plentiful and may hope to have the later flows augmented thereby. Conditions generally are promising for a good season.

The department about to enter on a new biennial term, with probably some changes in its personnel, it is desirable to know the condition of each office. You are directed therefore to report immediately to the office what books, papers and official records you have on hand. You are especially directed to report what volumes of the State Engineer's Reports you have.

During the coming season it is expected of you to gather information for your crop report at the close of the season.

In some cases these reports last year were complete and satisfactory, making a valuable addition to the data we have collected, and I desire here to extend my thanks and express my appreciation to such of you as have done your duty in this line.

In other cases the reports were incomplete from various causes, not entirely the fault of the commissioner; to such I would say that a little more effort and beginning in time will result in an improvement.

This office appreciates the fact that in some cases the managers of a ditch for some imaginary reason withhold information as to crops, etc., fearing a record of their actual doings. I would say that in such cases there is probably a motive and not an honest one, and it is then the commissioner's duty to use extra care and to observe more closely the doings under such canals, as there may be serious losses going on; storing of water may be practiced contrary to law, loaning and sale of water indulged in to the detriment of the rights of oothers, and enlargement and extension of canals or sale of unused water contemplated in the future.

It is the duty of the commissioner to observe closely the doings of each ditch, and make a record thereof, and you are directed to this end to carry a field-book in which is entered daily any changes in your district in regard to the shutting off or turning on of water and the amount so shut off and turned on, with the amount running in the ditch. You will note the condition of rating flumes and headgates, and report need of repairs or of rating to your superintendent or to this office, and use your best efforts to have the ditches put in proper condition.

To those who have not filed reports heretofore, I would say that the law requires you to make such reports, and that data for them can be gathered while performing your regular duties, that there is scarcely any necessity of your having to spend any extra time, and that you having accepted the office with the full knowledge that this was among your duties have no excuse for failing to comply.

This office will never be unreasonable, but it will insist on the proper observance of the law.

The law regarding the transfer of water passed two years ago requires transfers to be made through the district courts, being in effect the obtaining of a new decree; no transfer will therefore be made without such court decree.

The law regarding temporary transfer is still in force. When application is made for transfer you will ascertain first, whether it is to save crops; second, whether interested parties have been properly consulted; third, the transfer must be temporary and for emergencies only; it seems that a week in the month should be enough; fourth, and most particular, you should make no loan of water which does not belong to the ditch making the loan; and in this connection I would say that water does not belong to a ditch unless it is being used beneficially. The simple fact that a ditch has a decree gives them no right to the water unless they can use it beneficially; and after the users under the ditch have irrigated their crops and have no further use for the water the water belongs to the next priority needing it.

A few bills relating to irrigation were enacted by the last session of the legislature, and as soon as they are disposed of by the Governor we will issue another circular letter embodying the principal features, so far as we can, together with instructions relative to collecting data concerning reservoirs, etc.

In conclusion, I would say that I hope the cordial relations between the irrigation officials will continue and that we will be able to accomplish a great deal for the good of every district and division.

I am glad at this time to announce that the prospects are better for this office doing more in the way of rating and gauging than ever before, and that more intimate relations between it and the commissioner are probable, as we expect to devote considerable more time to exclusively irrigation matters than has ever been done before.

Very truly yours,

ADDISON J. McCUNE,
State Engineer.

INSTRUCTIONS FOR THE PREPARATION OF PLANS AND SPECIFICATIONS FOR THE CONSTRUCTION AND REPAIR OF DAMS.

The Twelfth General Assembly passed an act providing that all dams more than ten feet in height or with reservoirs covering more than twenty acres, must be built under plans and specifications approved by the State Engineer, and the work must be done under his supervision as consulting engineer (see Session Laws of 1899, page 314). It also provides that no dam shall be deemed complete under the provisions of said act until the State Engineer shall give to the owners of such structure an acceptance of the same.

The following general instructions relative to the preparation of plans and specifications for construction or repair are suggested by this department:

First. A profile of the site, giving location and dimensions of the outlet, and also spillways and character of foundation.

Second. A cross-section and plan of the dam, giving full dimensions with slopes and width of crest and height of same above high-water lines; also full details of the outlet pipes or conduits, valves or gates and valve chamber.

For earth dams the cross-section should show slopes of not less than 2½ to 1 on upper face and 1½ to 1 on lower face, and the crest should be from 5 to 7 feet above high-water line, owing to conditions.

Third. Every plan should be accompanied by a map or plan of the reservoir site showing the location and dimensions of the spillway and a statement of the approximate drainage area and maximum rainfall during the most severe storms known. If the dam is to be built on a running stream the maximum known discharge should be given.

Fourth. Plans for masonry dams should give the class and weight per cubic foot of the materials entering into their construction, and the weight of one lineal foot of dam should be computed and tabulated for

each foot in depth, so that the total weight above any point may be known. Also the pressure of the water against the dam must be similarly computed and tabulated. The resultant of the weight of the dam acting downward and the pressure of the water on the up-stream face of dam must be shown fully on a diagram. A full statement must be made of the character of the work it is proposed to build and of the character of materials to be used.

Fifth. Timber dams must show a plan and cross-section of the proposed construction. The character and weights of the materials used should be given and the weight of one foot in length tabulated for each foot in depth. The plans should show in detail how the timbers are to be put together and the method of anchoring the same.

ADDISON J. McCUNE,
State Engineer.

Denver, Colo., July 27, 1901.

To the Superintendents and Water Commissioners:

Gentlemen—In view of the complications and the trouble which arise on account of ratings of ditches when the same are not in good condition, I find it necessary to issue the following instructions:

No ditch unless in good condition as to rating flumes and as to the ditch itself, especially as to the presence of sand, can be rated. There being but one point where conditions are stable, and that point being where the ditch is free from sand and sediment, it is useless to make ratings under any other condition. Therefore, when a rating is required and this office is requested to have it done you will inform the owners of this requirement, and where possible you will see personally that this condition exists before the representative from this office is called upon to make what in some cases is a very hard and expensive trip. Cases may arise where it is practically an impossibility for the company to maintain a clean ditch at all seasons of the year; under these conditions it will be necessary for the company to demonstrate to this office that they have made every effort to comply with the above requirements and are keeping the ditch in as perfect condition as conditions permit. Until it is proven that the above requirements are unreasonable or impossible it will be presumed that it is practicable to maintain a clean ditch.

I would state further that many of the ditches have not now proper sand gates; these must be put in and the best methods possible adopted for disposing of the sand and sediment which of necessity enter the ditch. A rating having been made and the table furnished you, you will adhere strictly to it until you are otherwise instructed. If you have reason to believe that conditions have changed, rendering it necessary to have a new rating, notify this office immediately, with a full statement of the conditions as they did exist and as they exist since the change.

I would suggest further that when a representative of this office visits your district that you have all the ditches that need rating in condition for the work to be done. This office with its limited force finds it

necessary to use its time with the greatest economy and to so arrange its work that the greatest amount shall be accomplished in the shortest time. To this end you are asked to contribute by having conditions favorable to a good and permanent rating in as many ditches as possible at one time.

Yours truly,

ADDISON J. McCUNE,
State Engineer.

ACKNOWLEDGMENTS.

This Department is under great obligations to the various railroads of the state. Without the transportation furnished much of the work done would have been impossible of accomplishment, the expense fund of this office being barely sufficient to pay other unavoidable expenses.

The aid furnished by the water officials and the ditch companies in furnishing labor, and often board and lodging as well, has aided us materially, while their uniform courtesy has been very gratifying.

Acknowledgments are made elsewhere to the United States interior and agricultural departments, and to the State Agricultural College.

The recent death of Hon. E. S. Nettleton, who, as State Engineer for two terms, beginning 1883, inaugurated the present system of water administration in Colorado, makes it eminently appropriate to use his picture as a frontispiece for this report.

EXPENDITURES FROM THE STATE ENGINEER'S ASSISTANTS' FUND FROM DECEMBER 1, 1900, TO DECEMBER 1, 1902.

Appropriations for salaries of assistants for the fiscal years 1901 and 1902			$5,000 00
PAID.			
1901.			
Rod. S. King, deputy state engineer	$ 336 00		
John E. Field, deputy state engineer	1,692 00		
D. M. Wilhelm, stenographer	362 50		
Ray F. Walter, assistant	36 00		
C. B. Cramer, assistant	72 00		
		$2,498 50	
1902.			
Jno. E. Field, deputy state engineer	$2,022 00		
D. M. Wilhelm, stenographer	280 00		
A. L. Fellows, assistant	60 00		
R. W. Hawley, gager	75 00		
J. H. Hodgson, special deputy	10 00		
Shannon Lees, clerk	27 00		
Leone Fox, stenographer	26 00		
		$2,500 00	
			$4,998 50
Balance			$ 1 50

EXPENDITURES FROM STATE ENGINEER'S EXPENSE FUND FROM APRIL 1, 1901, TO DECEMBER 1, 1902.

Appropriation for the fiscal years 1901 and 1902			$1,000 00
EXPENDITURES.			
1901.			
Jno. E. Field	$ 85 80		
A. J. McCune	76 70		
M. D. Williams	76 40		
A. L. Fellows	149 85		
R. F. Walter	4 20		
Antone Jacob	90 60		
R. W. Hawley	16 45		
		$ 500 00	
1902.			
Jno. E. Field	$ 189 90		
A. J. McCune	137 68		
M. C. Henderlider	26 90		
A. L. Fellows	4 20		
W. H. Clark	15 00		
C. G. Elliott	16 53		
T. J. Dice	48 25		
R. W. Hawley	61 45		
		$ 499 91	
			$ 999 91
Balance			$ 09

EXPENDITURES FROM THE STATE ENGINEER'S GAGING FUND FROM DECEMBER 1, 1900, TO DECEMBER 1, 1902.

RECEIVED.		
Balance from last report		$ 403 40
Received from filing plats and statements and transfers of water rights	$ 842 55	
Received for examination of plans for dams and reservoirs	84 00	
Received for certified copies of records	131 00	
Received from fees		1,057 55
Received from general appropriation fund		100 00
Total		$1,560 95

EXPENDITURES.

1901.				
R. W. Hawley, gaging Arkansas river	$ 20 00			
A. L. Fellows, miscellaneous gaging	150 00			
R. F. Walter, ditch gaging	39 00			
A. J. McCune, acct. C. B. Cramer expenses	18 20			
M. D. Williams, ditch and seepage measurements	182 50			
A. J. Melvin, observer	7 50			
Carrie Osgood, observer	9 00			
Della Barber, observer	9 00			
H. W. Hood, observer	10 00			
		$ 445 20		
1902.				
A. L. Fellows, special gagings	$ 54 00			
R. F. Walter, ditch gagings	42 55			
M. C. Henderlider, ditch gagings	139 90			
C. C. Knight, river gagings	10 00			
Shannon Lees	46 00			
Carrie Osgood, observer	18 00			
Della Barber, observer	9 00			
F. W. Brown, observer	45 00			
J. B. Swan, observer	15 00			
Z. Swallow, observer	9 00			
Lloyd Jenkin, observer	22 50			
J. B. Regan, observer	22 50			
E. K. Blum, observer	9 00			
Roman Rodragan, observer	9 00			
Wm. Furniss, observer	9 00			
C. G. Graden, observer	9 00			
J. L. Prentiss, observer	15 00			
Annie Stewart, observer	9 00			
S. L. Purdy, observer	9 00			
A. Powell, observer	15 00			
Jas. Page, observer	15 00			
Humphrey Jones, observer	15 00			
L. L. Van Cleve, observer	15 00			
M. D. Smith, observer	12 00			
E. N. McKinney, observer	6 00			
R. E. Trimble, seepage measurements	93 00			
		$ 673 45		
			$1,118 65	
Balance in fund			$ 442 80	

LIST OF OFFICERS

IN CHARGE OF IRRIGATION IN COLORADO.

ADDISON J. McCUNE, State Engineer . . . . . Denver, Colorado
JOHN E. FIELD, Deputy State Engineer . . . . Denver, Colorado

SUPERINTENDENTS OF IRRIGATION.

NAME	Division	Appointed	Residence
James J. Armstrong	No. 1	April 12, 1901	Denver, Colo.
E. R. Chew	No. 2	April 12, 1901	Pueblo, Colo.
Wesley Staley	No. 3	April 12, 1901	Hooper, Colo.
E. D. Samain	No. 4	April 12, 1901	Durango, Colo.
A. F. Reeves	No. 5	April 12, 1901	Montrose, Colo.
Peter F. Reinhardt	No. 6	April 12, 1901	Steamb't Sp'gs, Colo.

WATER COMMISSIONERS.

Div. No.	Dist No.	NAME	Appointed	Residence
1	1	D. W. McSween	May 3, 1901	Brush
1	2	John A. Banning	April 16, 1901	Platteville
1	3	C. C. Hawley	April 13, 1901	Fort Collins
1	4	E. G. McKinney	May 29, 1901	Loveland
1	5	L. H. Dickson	May 2, 1901	Longmont
1	6	Thomas Kneale	April 13, 1901	Niwot
1	7	Alexander McLean	April 13, 1901	Golden
1	8	John P. O'Brien	April 13, 1901	Castle Rock
1	9	I. A. Van Gordon	April 13, 1901	Morrison
2	10	T. B. Pyles	April 16, 1901	Colorado Springs
2	11	Richard Devereaux	April 16, 1901	Salida
2	12	David J. Houston	April 17, 1901	Canon City
2	13	Louis Mueller	May 2, 1901	Westcliffe
2	14	Thomas J. Burrows	April 13, 1901	Pueblo
2	15	Melvin C. Goss	April 13, 1901	Pueblo
2	16	James K. Dempsey	April 13, 1901	Pueblo
2	16	C. M. Green	June 17, 1902	Pueblo
2	17	John W. Bowman	April 13, 1901	Manzanola
2	18	J. R. Aguilar	April 16, 1901	Aguilar
2	19	W. A. Garner	April 16, 1901	El Moro
3	20	F. W. Swanson	April 16, 1901	La Jara
3	21	George S. Lovett	May 6, 1901	La Jara
3	22	John C. Dalton	April 17, 1901	Manassa
1	23	Lent Hall	April 16, 1901	Fairplay
3	24	Meliton Albert	May 6, 1901	San Luis
3	25	J. M. Pitzer	May 2, 1901	Saguache
3	26	Argo Taylor	May 2, 1901	Saguache
3	26	John I. Palmer	April 7, 1902	Saguache
3	27	Michael White	April 16, 1901	Saguache
3	27	W. K. Manis	April 21, 1902	Saguache
5	28	E. E. Doyle	April 13, 1901	Doyleville

WATER COMMISSIONERS—Continued.

Div. No.	Dist. No.	NAME	Appointed	Residence
4	29	James S. Hatcher	April 29, 1899	Pagosa Springs
4	30	J. W. McCaw	April 16, 1901	Hermosa
4	30	E. F. Hill	Sept. 3, 1902	Hermosa
4	31	No commissioner		
4	32	No commissioner		
4	33	George W. Thompson	Jan. 30, 1902	Durango
4	34	Lewis Jarrott	May 6, 1901	Mancos
3	35	Charles MacMullan	May 6, 1901	Fort Garland
5	36	No commissioner		
5	37	A. Kalquist	May 6, 1901	Gypsum
5	38	George W. Hull	May 6, 1901	Basalt
5	39	Charles Frovert	May 1, 1902	Rifle
5	40	H. M. Payne	May 2, 1901	Delta
5	41	W. E. Obert	April 13, 1901	Delta
5	42	S. S. Sease	Feb 24, 1902	Colbran
6	43	J. D. Moog	April 16, 1901	Meeker
6	44	No commissioner		
5	45	E. L. House	April 17, 1901	Glenwood Springs
1	46	J. B. Riach	May 2, 1901	Hebron
1	47	W. D. Beckwith	May 2, 1901	Walden
1	48	Ernest W. Johnson	May 2, 1901	Glen Eyre
2	49	Ed. L. House	April 17, 1901	Rifle
5	50	No commissioner		
5	51	No commissioner		
5	52	O. F. Leroux	April 2, 1901	Sheephorn
5	53	A. R. Plowman	May 2, 1901	Burns
6	54	No commissioner		
6	55	No commissioner		
6	56	No commissioner		
6	57	No commissioner		
6	58	No commissioner		
5	59	No commissioner		
5	60	O. C. Springer	May 2, 1901	Pinon
5	61	William Vandergrift	April 13, 1901	Montrose
5	62	No commissioner		
5	63	No commissioner		
1	64	John W. Landrum	April 13, 1901	Sterling

WATER COMMISSIONERS—Concluded.

Div. No.	Dist. No.	NAME	Appointed	Residence
1	65	Proctor Doling	April 17, 1901	Wray
2	66	No commissioner		
2	67	George B. Wick	April 16, 1901	Las Animas
5	68	Henry S. Holliday	April 13, 1901	Ouray
5	69	Henry W. Royce	April 16, 1901	Rico

SAN MIGUEL COUNTY ROAD NEAR TELLURIDE.

CHAPTER I.

RECOMMENDATIONS.

Heretofore this Department has continually made recommendations for the betterment of the service and for changes in the irrigation laws.

In this report our principal plea is for an increased appropriation to enable the office to keep pace with the rapid growth of the state, and to co-operate as it should with the departments at Washington.

It is a well known fact that irrigation development in the West has been retarded more by lack of settlers than by lack of capital. Capital invested in irrigation lands can get no returns unless people can be had to farm the lands reclaimed, and these people must come as small farmers and home builders. Heretofore they have been kept away by the high price of land, by mistakes in the management of our ditches and by lack of knowledge of, and prejudice against, irrigation. The passage of the national irrigation act has given the subject great publicity in the East, and people, also, are beginning to see more and more the attractiveness of farming by irrigation. The cheap lands of the Mississippi valley and the Northwest are getting pretty well absorbed, and home seekers must look to the arid West for places to settle.

All these facts make it important that our state government should do all that is within reason to foster our agricultural growth. Colorado is at present the leading irrigation state of the Union, and should do all in its power to keep abreast of the times in this new irrigation development.

This office, having charge of the irrigation interests and the administration of irrigation laws, if properly supported and properly administered, will wield perhaps a more powerful influence for the development of our state than any other department. The condition of the finances of the state now

is such a that a liberal appropriation for this Department will not be a burden.

It is believed that the people of the state do not understand the position in which this office is placed with reference to the work laid out for it. The law says:

> He shall have general supervision over the waters of the state.
>
> He shall make careful measurements of the flow of the public streams of the state from which water is diverted for any purpose.
>
> He shall collect all necessary data and information regarding snowfall in the mountains.
>
> He shall approve designs and plans for construction, repair, etc., of all dams within the state above the height of ten feet, and shall act as consulting engineer on the same.
>
> He shall determine annually the amount of water which each reservoir shall be permitted to hold.
>
> He shall have general charge over the work of the different superintendents and water commissioners, and furnish data for an intelligent discharge of their duties.
>
> He shall prepare a report, etc., of all the operations of his department during each biennial period.
>
> He shall give his counsel and services to any state department when called upon to do so.

In addition to this the State Engineer is charged with the supervision of all the works of construction on roads and bridges under the internal improvements, besides the routine work of the office, hearing complaints and appeals and taking care of a voluminous correspondence. The office work alone is sufficient to occupy one competent person continually. The head of this Department is also expected to attend irrigation meetings and to give considerable time to a study of the needs of the state in every thing pertaining to irrigation. During the year 1901 the State Engineer and his deputy traveled over 40,000 miles in the discharge of their duties, much of it by private conveyance, besides attending to the routine work of the office, and even then many parts of the state were neglected.

It can readily be seen by the above that the State Engineer, with the present limited appropriation, can make but a poor attempt at carrying out the provisions of the law.

A study of the flow of our mountain streams should be made for reasons which were given in the tenth report. A study of the precipitation and run-off of the various drainage areas will be of great value, both as a basis for construction of power plants and for irrigation reservoirs.

We must not thoughtlessly go on with the construction of reservoirs as though there was an inexhaustible supply of water somewhere up in the mountains.

Already in a few of the streams has the storage appropriation reached so near the limit of run-off that it is advisable to do some figuring before going farther. If this work goes on without a proper study of the situation, we will, within a few years, have as much litigation over priorities for storage as we have had over ditch priorities. We believe it is advisable to require parties constructing reservoirs and ditches to obtain a permit from this office. Such a law would compel a proper study of the supply before proceeding with the work.

It is expected, of course, that the United States geological survey will continue the investigations of our water resources, perhaps on an extended scale, but there is enough work for both state and national government.

It might be considered too large an undertaking for the state to begin so extensive a study, but we are sure that in ten years or less the wisdom of it will be seen, and that it will be worth many times the cost; besides it would save much serious litigation.

As stated in the introduction, these streams which are used to transmit water from reservoirs down to the ditches that are to distribute it should be carefully studied, in order to deliver the same to the rightful owner without injury to any one.

Also, as stated in the introduction, we have derived much benefit by co-operation, both from the department of agriculture and the United States geological survey. Carrying out the spirit of the president's expression in his message that the general government desired to help those states which are prepared to help themselves, we should be prepared to keep up our end of this work. If we expect to get the assistance our position as a state merits from the new national reclamation act, we should be able to point out to the general government our most feasible irrigation projects for their consideration, and the state should be prepared to give the desired information, and should make sufficient appropriation to co-operate more fully with the geological survey in this work.

CO-OPERATIVE DRAINAGE INVESTIGATIONS IN COLORADO.

For the past four years the office of experiment stations of the United States department of agriculture has been studying the irrigation problems of Colorado, with a view to promoting the more economic and skillful use of water, and to aid in the settlement of legal and economic questions. A number of reports of this work have great interest to the state, and notably among these are Bulletins 86 and 119, dealing with the duty of water, and the bulletins of Col. E. S. Nettleton, and the Yearbook of the United States department of agriculture for 1901, dealing with the usefulness of reservoirs and their operation in Colorado.

During the past two years an arrangement has existed for systematic co-operation between this office and the office of experiment stations. The first result of this is a report on irrigation from the Big Thompson river, by John E. Field, Deputy State Engineer, published as Bulletin 118 of the office of experiment stations. Another result is the report which follows on the drainage of lands which have been injured or rendered unproductive by the seepage of water from irrigation canals and other sources. This investigation has been carried on by Mr. C. G. Elliott, agent and expert of the office of experiment stations, in charge of its drainage investigations. The greater part of the expenses of this work was paid by the office of experiment stations, the funds of this office only permitting of a limited assistance.

The value of the information contained in this report, the interest shown by the farmers in the localities visited, and the growing necessity for supplementing irrigation by drainage, leads me to believe that these investigations should be continued and be begun in the earlier part of the season, when the direct effects of over-saturation is observed.

As a result of this co-operation, the state of Colorado has been enabled to secure the services of a drainage engineer of wide experience at no outlay save the payment of some field expenses; and the wide range of Mr. Elliott's investigations, covering as it does all of the arid region, enables him to bring to the solution of our problems a knowledge gained in the other states where conditions are similar. It is understood that the office of experiment stations is willing to continue this co-operative arrangement, and I recommend that sufficient appropriation be made to place this office in a position

to secure their prompt inauguration and to have them extended over additional areas during the next two years.

We are constantly receiving requests for copies of the irrigation laws. This desire on the part of the people for better knowledge of the subject of irrigation is commendable, and should be encouraged. An appropriation should be made for a revision and recompilation of the laws, bringing them down to date, omitting all useless matter and putting them in the most intelligent and simple shape possible.

In the absence of statutes, judicial decisions determine to a very great extent the law, and in any compilation of the law, these should be made as plain as possible. Such a work would require considerable time and expense, but it should be so thorough and exhaustive as to make it an authority, and whoever is selected to do the work should be one capable of handling the subject as an attorney, yet familiar with irrigation from a practical and scientific point of view; one who is practiced not only in the law, but experienced in its administration and in the distribution of water.

PERMANENT GAGING STATIONS.

We earnestly recommend the beginning of construction by the state of permanent gaging stations on some of our most important streams. They are especially needed on the Arkansas and South Platte rivers, on account of the use of these two streams as conduits for delivering water from large reservoirs, viz., the Twin Lake reservoirs and the Cheesman lake. An estimate was made by this office on the Platte river the past season, and it was found that $2,000 will be ample to build a first-class station; and an equal amount will suffice for the Arkansas. This money can be taken from the internal improvement fund, and no better use can be made of it.

Some complaint has been made concerning the administration of the law regulating the distribution of water from reservoirs which use the natural streams for conduits. While such complaints have not come direct to this office, we have felt that injustice has been done in some cases, but we have been unable from lack of funds and time to investigate the conditions and to enforce the law regarding the use of registering devices. The law permitting the use of streams for conduits has been the means of developing large enterprises. Yet it will be in some instances difficult and expensive to properly administer. Many of the problems connected with it will have to be worked out by practice and experience. Better

facilities for measuring the streams along the line of transmission of the water should be provided, in order to keep a check on the volume delivered and to determine the loss in such transmission. No study, except on a small scale, has been made of the loss of water in transmission. Conditions are so different on different streams, and so different on the same stream at different stages, that each stream will have to be studied separately. This work will involve considerable expense, and must be done by parties interested, unless this office can get increased appropriations.

The most practical method of checking the amount of water used from a reservoir, where the channel of the river is used as a conduit, seems to be to have the capacity of the reservoir known for each foot in depth, a gage rod in the reservoir and a rating flume in the inlet and outlet. An automatic register should be used in the outlet at least, and where the reservoir is difficult of access, where it is not readily visited by the commissioner, an automatic register should be used in the inlet and outlet also.

With the above data and appliances, when it is desired to use water from the reservoir the gage height is accurately noted, the amount desired is then turned out which is readily determined by reading of the gage in the outlet rating flume.

The gage in the inlet rating flume indicates the inflow and the difference is, of course, the amount being drawn from the reservoir.

The canal below is entitled to this difference, less the percentage allowed for evaporation and loss.

In practice the water is turned into the canal only after the reservoir water has reached the headgate thereof; this occupies from one to five days.

While the water is being run the amount flowing out or in should be increased or diminished as the inflow increases or diminishes. When this can be readily done the problem is not hard, but when it can not, as is often the case, the only check is to read the gage in the reservoir carefully when the run is over.

The difference of levels of the water before and after the run with the table of capacities will indicate the total amount run off the reservoir. A careful account having been kept of the amount allowed to pass into a canal a balance can be struck indicating the amount still due the canal and the one to five days intervening between the date when the reservoir was opened and the date when the ditch was

first allowed to draw water will allow sufficient time in which to make the accounts balance by delivering a greater or less amount to the ditch.

Even where an account can be kept of the inflow this means should always be employed as a check on the other method.

One difficulty, and what gives rise to a great deal of controversy and numerous complaints, is that the rise in the river at the headgate of the canal seems to be much less than what the amount of reservoir water should give. This is due largely, I believe, to the fact that the small ditches can often draw water with the increased volume in the river which could draw none with the river at its former stage; also many ditches will draw a slightly increased amount of water on account of the increased pressure on the headgates due to the increased depth of water.

The law passed by the Twelfth General Assembly in relation to the putting in of headgates and rating flumes and the repair of the same was enforced to a considerable extent during the last two years, and many districts which had heretofore had neither of these necessary appliances are now well supplied. In some of the districts, in sections near the heads of the streams and where the ditches are small, especially if the priorities are late, the greatest difficulty is met with in enforcing the law. In such sections their inaccessibility, the general ignorance of the rights of priority, and the fact that they have never been interfered with before cause the people to resist the orders of the commissioner. When ditches were closed by him they would be immediately opened upon his departure. Complaints to the district attorney were often made, he refusing absolutely to act; in other cases where he did act and where parties were caught actually opening their gates, contrary to the orders of the commissioner, the district attorney, failing to catch the true status of the case, allowed evidence to be introduced going to show the rights of the parties to water. He did not seem to appreciate the fact that it was a police regulation necessary to the proper distribution of the water. While the defendant might have been entitled to water, there was a regularly recognized method by which he might obtain it; that is, by application to the water commissioner. The case is in all points similar to a person having a deposit in the bank; the fact of his having a deposit does not justify him in breaking open the vaults, going in and taking out his

money; it is necessary for him to proceed along the regular lines laid down by the law and custom if he wishes to withdraw his funds. An additional difficulty lies in the fact that the district and county courts and the district attorney are generally in sympathy with the culprit. They consider it loyal to stand by their section of the country. In some sections it is even boasted that any district attorney or court which executed the laws in regard to irrigation would be most assuredly defeated at the next election.

When districts have been supplied with proper headgates and rating flumes it is then necessary to have the ditches properly rated; without this the devices are of little use. During the last two years a number of districts have been visited, notably, Nos. 11, 20, 21, 25, 26 and 27, and most of the ditches rated. Each district requires a week or more, and involves considerable expense for traveling and the pay of the deputy. If the ratings were permanent and the ditches did not change this would be a small item, but with the constant changes is it necessary to visit the ditches at least once a year. Many should be visited once each month. It will be readily seen that it is impossible with the present appropriation to do the work satisfactorily. The department should be reorganized with reference to this work. Water superintendents and water commissioners should be competent to handle a meter and to rate the ditches. The state should purchase a dozen meters and put them in the hands of this department to be distributed to the superintendents and commissioners where most needed. With such appliances the ditches could be rated at any time, and the commissioner or superintendent suspecting a change or an error in the rating could test it without having to send to the State Engineer's office and have a deputy travel from one hundred to four hundred miles to make the rating. In cases of disagreement this office would act as referee, and could, when necessary, check the work of the superintendents and commissioners.

There is a strong sentiment among the people in favor of abolishing the office of the Superintendent of Irrigation, and putting all commissioners directly under the charge of this office, and correspondingly increasing the appropriations necessary for it. We are not prepared to say that such a plan is feasible, but there might be a consolidation of the divisions. There is but little need of superintendents for both divisions 3 and 4, as there is no stream in either of these two divisions which contains within its drainage boundary

more than one district. To abolish the office of superintendent would possibly not lessen the expense. (The superintendents cost the people of the state about $5,000 in 1901.) The amount of work accomplished, however, would in all probability be greater and more satisfactory. If the superintendents could be made deputies to the State Engineer it would accomplish what has been recommended in nearly every State Engineer's report; that is, that the State Engineer should be the head of the Department in fact as well as in name. Such deputies, besides attending to the duties now devolving upon the superintendent, could do much other work of value to the Department. The pay of the superintendent would then be met by the state, instead of by the counties, and a much more equitable distribution of the expenses would be obtained, as well as eliminating the uncertainty of receiving proper compensation, which is now a great annoyance, not only to the superintendents and to the entire irrigation Department, but also to the counties.

In view of these circumstances, it is believed that the only solution of the difficulty lies in the formation of a state board of irrigation, composed of persons familiar with the laws, practical administration and customs in our state. Such a commission could be presided over by, or have for one of its members, a judge, who could pass upon a legal phase of the different cases; but the other members should determine matters of fact, and make necessary examinations upon the ground. Such a court could not only hear and try cases of dispute, but should also take the evidence and render the decrees.

This idea is brought out in Bulletin No. 118 of the agricultural department. Commenting upon the peculiarities of the decrees it says:

The peculiarities of the decrees in District 4 have been discussed, but all the above reasons and those previously mentioned do not explain, nor can they excuse all the mistakes made. No man, no matter how good a judge or attorney, is competent to render decrees unless he has had practical experience in the handling and distribution of water, and for this reason it seems necessary either to remove the settling of priorities from the judiciary or to supply them with such expert aid as is necessary.

A board consisting of men trained in the service who recognize its needs, the difficulties and dangers likely to arise, and who can and will make examination on the ground to settle disputed facts, seems far superior to a judge who has had at most little practical experience with water, who is accustomed to handling civil cases with rules of procedure scarcely applicable to irrigation cases, and who in the press of other work can not take the time necessary to become personally familiar with the

case on the ground as well as in the court room. To go on adding reasons for such a change, in view of the conditions of the decrees already rendered by the courts, is entirely unnecessary.

In conclusion, we would recommend, as has been done heretofore, a law requiring the State Engineer to examine and make report upon the ditches of each district before decrees are entered. As to the old districts, however, where the decrees have been fixed, the only solution seems to be for the State Engineer to examine each ditch, reservoir and decree, and upon his report to the Board of Irrigation, or to a proper court, and after proper hearing, that portion of the decrees which is proved to be excessive should be declared to be abandoned. The ideas expressed in the closing pages of Bulletin No. 118, referred to before, gives a very clear idea of some of the difficulties encountered by this office, and we therefore quote the following:

Enlargement is productive of more evils than transfers. Transfers are open, subject to examination and question. Enlargement is a slow, insiduous, intangible process of taking more and more water from the river and of depriving later appropriations of benefits which they have before enjoyed. The simple process of cleaning a ditch, if well and thoroughly done, may be made in a few years to double the capacity. An examination and record of the present ditch capacities would prevent much of this and declared abandonment, resulting in practically a new set of decrees, which stop it altogether.

The decrees all contain one element so indefinite that one is at a loss how at this time to apply a remedy, though in future decrees this might be more specifically stated—that is, the time element. A decree purports to establish the maximum amount of water that can be diverted at any time. It is left to conjecture, however, for what length of time the water is so run. Under the conditions existing at the time appropriations were made for the early ditches, and extending even to the time of the decree, the water was used quite differently from what it is at present. The crops were all early maturing and requiring little water. Now, however, both early and late crops are raised, the result being that instead of having little use for water after July it is now demanded for August and September as well. Formerly water was run on the land perhaps one week in the month; now with larger ditches, larger and more diversified crops, it is run every day in the month. This, then, is an increase in the length of the season and of use from an intermittent to a continuous flow, with the result of a largely increased acreage irrigated and actual volume diverted though the number of cubic feet per second may be no greater.

This enlarged use is made possible by the segregation of the land and water under the rulings of courts and brings up a consideration of the fourth item in the summary on page 64.

Numerous cases have been tried in the state in which the right to transfer water has been confirmed. With the conditions of excess decrees, it is to be expected that the excess, when water becoms valuable, will, if possible, be used. The water becomes an article of sale and purchase, and, while as stated in the section on laws, transfer, extension and enlargement are benefits to the community as a whole, confiscation of the property of the individual results for the benefit in particular of the holders of an old decree and of the community in general. With decrees more definite as to length of time and use and limited in quantity to the needs of the land irrigated, transfers would be a benefit, as they would encourage consolidation of ditches and economy of use. Conditional decrees could be granted dependent on the completion of extensive works and the actual reclamation of the land within a reasonable period.

In the administration of the irrigation department, one must contend with the acts of those who believe themselves to have been wronged and who by force seek to maintain their rights, but discretionary power of the officers has been so curtailed and limited that they are often forced to do things against both their judgment and inclination. Every irrigation official should be clothed with more discretionary power, and the decisions of the State Engineer should stand until the courts decide adversely, instead of being overruled by injunction. An official who is sworn and under bonds to do his duty is enjoined from doing this duty. The presumption of impartiality is as strong in him as in a judge; his ability to judge of a case is superior; he is familiar with the law and customs; he knows, by long exercise of his duties, the priorities, the needs, and the rights of the ditches; he knows almost by instinct the effect of certain actions and decisions; he has knowledge which neither laws nor decrees, nor books, nor records can give; he has seen the effects actually worked out on the ground; he is vitally interested in the good conduct of his office, and he is subject to immediate removal in consequence of any misconduct. It is simply absurd that the court should presume without investigation, and ex parte proceedings to set aside his rulings.

CONCLUSION.

In the foregoing pages, as far as possible, facts as ascertained from personal observation have been given, and criticism of doubtful points have been avoided. An attempt has been made to give an outline and something of a history and the sequence of events which led up to the legal contests, said by some to be only the beginning, but which are more probably the beginning of the end. Other nations have had nearly the same questions and difficulties to meet, and found the solution of their troubles and worked out their own salvation. With them it required centuries for final settlement. In the United States the progress made in Colorado in one short generation gives no reason for discouragement. An efficient system of administration has been worked out, and a system of adjudication has been adopted, which needs only a better knowledge of the requirements of irrigation practice to make it satisfactory.

CHAPTER II.

INTERNAL IMPROVEMENTS.

The Thirteenth General Assembly made no appropriation from the internal improvement fund except that of $25,000 for State Canal No. 3, consequently the work of this Department for the biennial period just closing had to do with those appropriations under which the work was not completed at the issuance of the tenth biennial report. The following is a description of the work done during the present biennial period:

PALMER LAKE CYCLE PATH.

It was found impossible to procure a right of way for the path without absorbing a large part of the appropriation, consequently nothing has been done since last report. The balance remaining from last statement, viz., $4,455.25, stands to the credit of that fund.

THE GARFIELD COUNTY ARTESIAN WELL.

As stated in the tenth report of this office, a contract was let to The Bullen Bridge Company to sink a well at Antlers to a depth of 525 feet, for $2,400, and case with four-inch casing. A deduction of $154.40 was made from the original contract price for casing not put in.

The work progressed very slowly and was finally completed in June, 1901. No artesian flow was obtained, although water rose to within a few feet of the surface.

STATEMENT OF EXPENDITURES.

Appropriation		$2,500 00
Paid by Garfield county, State engineer expenses		5 00
Denver Post, two advertisements	$ 16 05	
J. C. Cook, inspection of work	40 00	
The Bullen Bridge Company, on contract	2,245 60	
D. M. Wilhelm, typewriting and office work	10 00	
A. J. McCune, expenses	14 25	
Rod S. King, trip of inspection	5 00	
New Castle Nonpareil, two advertisements	17 62	
Balance in fund, unexpended	156 48	
Total	$2,505 00	$2,505 00

CHEYENNE COUNTY ARTESIAN WELL.

After many delays a contract was let to The Bullen Bridge Company to sink a well to a depth of 750 feet and case the same with four-inch casing, for $3,800. (See Tenth Biennial Report.) A clause in the contract provided that the board of construction could, at their discretion, stop the work at any time they were satisfied it was impracticable to sink deeper, and pay for the work done at the rate of $5.06 per foot. Work was stopped at a depth of seven hundred feet, and settlement made according to contract. No artesian water was obtained.

STATEMENT OF EXPENSES.

Appropriation		$4,000 00
W. E. Hickman, inspector	$ 45 00	
Cheyenne County Republican, advertising	14 01	
Rocky Mountain News	8 81	
D. M. Wilhelm, typewriting and office work	10 00	
The Bullen Bridge Company, on contract	3,542 00	
Balance unexpended	380 18	
Total	$4,000 00	$4,000 00

SAGUACHE COUNTY ARTESIAN WELL.

As stated in the Tenth Report of this office a contract was let to the Bullen Bridge Company to sink the well provided for under this bill to a depth of 1,100 feet and case with four-inch casing for $4,750.

The contract provided that work could be stopped at the discretion of the board and work settled for at the rate of $4.32 per lineal foot.

The work was stopped at a depth of 1,043½ feet and the contract settled upon the above named basis per foot. No artesian water was obtained.

STATEMENT OF EXPENDITURES.

Appropriation		$5,000 00
O. D. Bryan, expenses attending meeting of board of construction, and for advertising	$ 17 02	
Rod S. King, expenses of trip to report on location	9 50	
Denver Post, advertising	6 83	
O. D. Bryan, for inspection and expenses	58 00	
D. M. Wilhelm, typewriting and office work	10 00	
The Bullen Bridge Company, on contract	4,177 64	
Balance unexpended	721 01	
Total	$5,000 00	$5,000 00

ARAPAHOE AND MESA COUNTY STATE ROAD.

An outline of the policy decided upon and manner in which the funds provided in this appropriation were to be applied was given in the Tenth Biennial Report and need not be repeated here. Work was done under this appropriation in Garfield, Eagle, Lake and Park counties. The work in Garfield county consisted of the construction of a wagon road through the canon of the Grand river from the Eagle county line to Grizzly creek, a distance of ten miles, where it connected with a road already in use, thus giving an outlet through the canon. This contract for this work was let to Henry Morrill for $20,000. After the road was completed the Board applied $1,000 additional to the construction of guard-railing along some of the most dangerous points. The contract was completed in April, 1902. The line was surveyed by E. B. Sawyer and work was supervised by M. E. Morrow.

The work in Eagle county consisted of the construction of about three miles of wagon road extending from the bridge across Grand river at Dotsero to the Garfield county line to connect with the work done in Garfield county; the construction of a steel bridge seventy-five feet long on concrete abutment and tubular piers with a twenty-foot wooden approach span at the town of Eagle; a fifty-foot steel bridge on concrete abutments across Eagle river one mile below the town of Red Cliff, and a twenty-two foot steel bridge on concrete abutments across Turkey creek at the town of Red Cliff. This work was let to the Bullen Bridge Company for $6,505, and was completed in December, 1900.

ARAPAHOE AND MESA COUNTY ROAD. VIEW IN GRAND RIVER CANON.

The work in Lake county consisted of the reconstruction of 6,000 feet of road, being a portion of the Leadville and Red Cliff county road.

Proposals were received on September 16, 1901, and the contract was awarded to Thomas Andrew, of Leadville, for the sum of $1,200. The line was laid out and work supervised by Thos. W. Joycox, city engineer of Leadville. The contract was completed and accepted in October, 1901.

The work in Park county consisted of the construction of three steel bridges on concrete abutments across the Platte river—two of forty feet and thirty-four feet in length respectively at Llangollen and one thirty-four foot steel bridge on concrete abutments between Glenisle and Baileys. Surveys were made for a short piece of road just above the town of Baileys to get rid of two river crossings, but after the line was located the owner of the land demanded an exorbitant sum for the right of way and the work was abandoned.

Bids were received on the 18th day of September, 1901, for the construction of the bridges and the contract let to M. J. Patterson for $3,267. The work was completed and accepted in May, 1902.

STATEMENT OF EXPENDITURES.

GARFIELD COUNTY WORK—

E. B. Sawyer, work on survey	$ 235 25	
A. J. McCune, expenses of inspection	63 15	
H. B. Morrill and Sidney Broughton, in full for section 1	4,000 00	
M. E. Morrow, superintendence	311 60	
D. M. Wilhelm, typewriting and office work	20 00	
H. B. Morrill and Sidney Broughton, in full for section 2	6,000 00	
Ed. T. Taylor, money advanced for surveys	235 60	
H. J. Holmes, advertising	8 22	
F. W. Allen, extra work for guard rails	75 00	
H. B. Morrill, in full for section 3	10,000 00	
H. B. Morrill, for extra work ordered by the engineer	175 00	
K. C. Vorhees, livery hire	4 50	
A. J. McCune, expenses of inspection and incidentals	37 15	
E. B. Sawyer, making profile of road	19 80	
M. E. Morrow, superintendence	400 00	
H. B. Morrill, constructing guard rails	1,000 00	
Theo. Rosenberge, running grades	8 46	
Evening Telegraph, advertising	8 35	
Total		$22,619 03

The expenses of survey of road in Eagle county are included in the above.

EAGLE COUNTY—

Ben L. Cress, inspection of work	$ 38 40	
Theo. Rosenberge, inspection of work	39 30	
D. M. Wilhelm, typewriting and office work	10 00	
A. J. McCune, expenses of inspection	20 00	
Lee R. Willitts, superintendence four days	20 00	
Nelson Yost, work of surveys	14 00	
Eagle County Times, advertising	16 25	
Ed Sloughter, advertising	9 40	
The Bullen Bridge Company, bridges	5,830 00	
The Bullen Bridge Company, road work	675 00	
Total		$ 6,672 35

LAKE COUNTY—

The Leadville Publishing Company, advertising	$ 12 19	
The Denver Post, advertising	8 44	
The Evening Telegraph, advertising	13 57	
A. J. McCune, expenses of inspection	13 00	
Thos. W. Joycox, surveys and superintendence	82 00	
Thomas Andrew, on contract	1,200 00	
Total		$ 1,329 20

PARK COUNTY—

Fairplay Flume, advertising	$ 12 19	
The Denver Post, advertising	8 97	
Colorado Springs Telegraph, advertising	13 57	
A. J. McCune, expenses of inspection	12 00	
Benj. Tyler, team and assistance on survey	33 50	
M. D. Williams, C. E., survey	20 00	
M. J. Patterson, on contract	3,267 00	
C. H. McArthur, grading approaches to bridges	167 50	
Total		$ 3,534 73

SUMMARY OF EXPENDITURES, ARAPAHOE AND MESA COUNTY STATE ROAD.

Total appropriation		$35,000 00
Garfield county	$22,619 03	
Eagle county	6,672 35	
Lake county	1,329 20	
Park county	3,534 73	
Balance in fund	844 69	
Total	$35,000 00	$35,000 00

A reconnoissance of the Eagle river canon below Red Cliff and of the canon of the Grand river in Mesa county above the mouth of Plateau creek was made to determine the cost of building through the same. Five and one-half miles of road will be required to get through the Eagle river canon, costing, including a bridge across Homestake creek, about $12,000. In the Grand river canon the distance from the mouth of Plateau creek to the head of the canon is eight miles, which will cost about $11,000. From the west end of Lake county road across Tennessee pass to the head of Eagle river above Pando, the old railroad track could be repaired at a cost of perhaps $1,200 and utilized for a wagon road, making an excellent highway across the range on a maximum grade of 4 per cent. On the eastern slope an expenditure of about $10,000, from the mouth of Turkey creek above Fort Logan to the town of Baileys in Platte canon, would be a valuable improvement. These suggested improvements would make a fair road across the state from Denver to Grand Junction.

SAN MIGUEL COUNTY ROAD.

House Bill No. 183, Session Laws, 1899, appropriated $8,000.00 for the purpose of constructing a wagon road from near the mouth of Marshall creek, above Telluride, along the north side of San Miguel valley to the Bridal Veil basin. The State Engineer and the board of county commissioners of San Miguel county constituted the board of construction. The funds for this appropriation were not available until 1901, but the county commissioners of San Miguel county, in order to advance the work as rapidly as possible, guaranteed personally the expenses of the survey, and Mr. H. C. Lay, C. E., of Telluride, was employed to locate the line. An attempt was made to let a contract in October, 1900, so that, on account of the high altitude and the shortness of the season, work could be begun at the earliest possible date in the following spring. No satisfactory bids were received, and the business was laid over till the following season. Bids were called for on September 30, 1901. No bids were received within the appropriation available, and it was decided to make some changes in the location which would cheapen the construction, and Gibbs & Greenwood, civil engineers, of Telluride, were employed to relocate the line. On October 2d the contract was let to M. F. Young, Peter Hanson and Thomas Richards for $7,000. The work was completed in September, 1902, and considering the rugged character of

the county over which the line runs, it was done in a very satisfactory manner.

STATEMENT OF EXPENDITURES.

Appropriation		$8,000 00
W. H. Stonsbech, on account of surveys	$ 546 95	
Joseph Kent, work on surveys	6 00	
A. J. McCune, traveling and incidental expenses	52 80	
D. M. Wilhelm, typewriting	5 00	
H. C. Lay, surveying account	24 00	
Gibbs & Greenwood, resurveying on contract	250 00	
Telluride Journal, advertising	45 45	
C. W. Gibbs, superintendence of work	69 50	
Peter Hanson, on contract	7,000, 00	
Balance in fund	30	
Total	$8,000 00	$8,000 00

CLEAR CREEK COUNTY ROAD AND BRIDGE.

House Bill No. 381, Session Laws of 1899, appropriated $5,000 for the repair and construction of the main highway from dividing line of Jefferson and Clear Creek counties and to the town of Empire, in Clear Creek county, and also for a steel or iron bridge across North Clear creek at Big Bar, about two miles below Idaho Springs.

The State Engineer and the board of county commissioners of Clear Creek county constituted the board of construction. The bill provided that the road and bridge work might be contracted for under separate bids. Plans were adopted for the Big Bar bridge, and proposals for its construction were received September 21, 1900, and the contract awarded to M. J. Patterson for $2,000. The bridge is a steel lattice girder, sixty feet in length, on steel legs set in concrete footing. This structure was completed in February, 1901. After inspection of the line of road to be benefited by this appropriation it was decided that the public would be best benefited by spending the greater part of the remainder of the fund in the construction of a new bridge across Clear creek, immediately above the town of Idaho Springs, the old bridge being in a dilapidated and dangerous condition. Two propositions had to be considered. The exit of the Big Five tunnel was near the north end of the bridge and the approach to it was a rapid descent, making it a dangerous point. Raising the bridge to a grade above the

mouth of the tunnel would necessitate a very heavy fill at both approaches. The bridge alone would cost more than the amount available in the fund, and Clear Creek county did not feel justified in incurring so heavy an expense. After some delay the Big Five Tunnel Company agreed to make the necessary fills if the state and county would build the bridge on the high grade. Consequently, bids were received September 7, 1901, and the contract let to M. J. Patterson for $3,494 for the bridge work and $200 for 1,070 cubic yards of grading on the road above the bridge. The structure is of steel, eighty feet in length, on tubular piers, with a twenty-two-foot wooden approach span at each end. The work was completed in June, 1902.

STATEMENT OF EXPENSES.

Appropriation		$5,000 00
Appropriated by Clear Creek county		792 61
Denver Post, advertising	$ 8 01	
Jerry Buckley, expenses attending meetings	8 10	
Thomas Coppard, superintendence	65 00	
D. M. Wilhelm, office work and typewriting	7 50	
M. J. Patterson, on Big Bar bridge contract	2,000 00	
M. J. Patterson, on road and bridge contract	2,911 39	
Paid by Clear Creek county	792 61	
Total	$5,792 61	$5,792 61

THE GUNNISON RIVER BRIDGE.

House Bill No. 45 of the Twelfth General Assembly appropriated $6,000 for the purpose of constructing a bridge across the Gunnison river, in Mesa county, near the town of Whitewater. The Governor, State Engineer and chairman of the board of county commissioners of Mesa county constituted the board of construction.

As provided by law, the board advertised for plans, and those of the Wrought Iron Bridge Company were adopted Proposals were received on the 16th day of August, 1900, and the contract was awarded to the Bullen Bridge Company for the sum of $7,250, the board of county commissioners of Mesa county having guaranteed the balance required above the appropriation to complete the structure.

The bridge consists of two spans of 144 feet 9 inches each, with sixteen-foot roadway, on masonry abutments and tubular piers five feet in diameter, and is a very sub-

stantial structure throughout. When the foundations were sunk it was found necessary to go deeper than the plans called for, involving considerable extra expense, which was borne by Mesa county, as was also all incidentals, such as superintendence, plans, etc.

STATEMENT OF EXPENDITURES.

Appropriation		$6,000 00
Paid by Mesa county on contract		1,250 00
Paid the Bullen Bridge Company on contract	$7,250 00	
Total	$7,250 00	$7,250 00

WHITE RIVER BRIDGE.

(See Tenth Biennial Report.)

The contract for the construction of White river bridge was let to M. J. Patterson on November 30, 1900, for the sum of $1,916, the county commissioners guaranteeing to construct the approaches and provide the right of way to it. The bridge consists of one combination steel and wood span one hundred feet in length, the truss members being of Oregon fir, and a twenty-two-foot approach span, all on red spruce crib pier and abutments. The work was done under the supervision of J. D. Moog, C. E., of Meeker, Colorado, and was completed in April, 1901.

STATEMENT OF EXPENSES.

Appropriation		$2,000 00
Denver Post, advertising	$ 5 32	
A. J. McCune, expenses locating bridge	14 25	
D. M. Wilhelm, typewriting and office work	7 50	
J. D. Moog, superintendence	48 00	
M. J. Patterson, on contract	1,916 00	
Balance unexpended	8 93	
Total	$2,000 00	$2,000 00

MORGAN, WASHINGTON, YUMA COUNTY ROAD.

Seventy-five hundred dollars for the improvement of roads along the line of the Burlington railroad was appropriated by the Twelfth General Assembly. As funds were not available therefor until the spring of 1901, no work was attempted before that time. By the bill, $2,500 was to be spent on each of the three counties.

In June, 1901, a representative from this office and the chairman of each of the counties met and formulated plans for carrying on the work along such lines as would be of the greatest benefit and at the same time so make the improvements that each piece of work done would form part of a general plan for building a continuous and complete road from the state line to the westerly boundary of Morgan county. The amount of funds available was so small that the work done would of necessity be separated by a considerable distance. On account of the great cost of building some parts of the road as it should be, it was deemed advisable to build in the less difficult places and in places most traveled, or where by the construction of a short piece of road over boggy or sandy places good portions already in existence might be joined.

The Morgan county portion of the appropriation was expended for a bridge across Bijou creek on the main road running from Fort Morgan westerly. It is a wooden bridge four hundred feet long and fourteen feet wide, on piles. After advertising for bids, F. E. Baker, being the lowest bidder, the contract was let to him for $1,488, and after the bridge wás completed additional wings were added at an expense of $25. Subsequently, approaches of earth were made to the bridge. The items of expenditure were as follows:

Appropriation		$2,500 00
F. E. Baker, plans of bridge	$ 20 00	
Advertising	5 00	
F. E. Baker, contract on bridge	1,488 00	
F. E Baker, additional wings	25 00	
A. D. Clem, inspecting and expenses	29 00	
J. E. Field, services and expenses	52 92	
S. F. Shadowen, approaches to bridge	295 00	
		1,914 92
Balance		$ 586 08

No work was done on the Washington county portion of the road. Two trips were made to the county and the road examined. Delays occurred on account of obtaining rights of way, and the disposition of the county chairman seemed to be that the money would not be beneficially expended if the provision of the act requiring the road to be built near the Burlington railroad was adhered to; in addition, that there appeared to be, in the northern end of the county, places where the money could be most advantageously

used. However, if the money had been spent along the lines laid down in the bill, it would have formed a link for which additional appropriations would have been necessary in building a continuous road from the state line westward.

Under the circumstances, the State Engineer did not feel justified in beginning the work, and the matter was allowed to go over, and can now be disposed of as the legislature may direct, or the incoming board of construction direct.

The Yuma county fund was expended for a small bridge at the town of Laird and in improving the existing wagon road from the state line westerly through the towns of Laird and Wray to a point some twelve miles from the latter place, making in all about twenty miles of road in very good condition.

The road was built by improving the worst places, which, being deep sand, required a surfacing of rock or clay. These materials were scarce in places, and necessitated a haul of several miles.

Any future appropriation should contemplate the expenditure of at least $1,000 per mile, as the portions remaining to be improved are quite difficult and require a much longer haul to obtain suitable materials for surfacing.

The items of expenditure are given below, the work being done by day labor—teams with drivers receiving thirty-five cents per hour, and men seventeen and a half cents per hour.

In order to complete the road to the point selected, it was found necessary to exceed the amount appropriated. This excess the county bore. The county road overseer was in charge of all the work except the bridge.

EXPENDITURES.

Appropriation		$2,500 00
J. E. Field, expenses of inspection	$ 33 17	
Joseph Brower, chairman, expenses	7 90	
Grant & Sons, bridge contract	205 00	
Labor	2,253 60	
		2,498 67
Balance unexpended		$ 1 33

GUNNISON TUNNEL, MONTROSE END.

STATE CANAL NO. 3.

The Thirteenth General Assembly passed a bill providing for the construction of a canal to be known as State Canal No. 3, commencing at the most feasible point on the Gunnison river and running thence in a westerly direction to the Uncompahgre river valley, thence, with laterals, to cover and redeem lands in Montrose and Delta counties, and appropriated $25,000 out of the internal improvement fund towards the construction of the same. The board of control appointed by the Governor consisted of John J. Tobin, of Montrose county; George E. Dodge and Hon. C. M. Hammond, of Delta county. The bill also provided that the State Engineer, under the direction of said board of control should survey and locate the canal and tunnel. Before the survey was ordered begun by the board, however, the United States Geological Survey began a preliminary survey of the tunnel site, which was the principal feature of the proposed system, this work of the general government resulting in a saving of several thousand dollars to the state. In September, 1901, the work of the survey had progressed so far as to determine the feasibility of the project and the final location of the main tunnel. The board employed J. A. Curtis, C. E., of Delta, to make the final location of this main tunnel, and work was begun at the Montrose end of the same. The board also did considerable work in preparing maps of the valley and collecting data as to the amount and character of land which can be watered by the system, with a view of interesting capital in the enterprise.

As stated above, work was commenced on the Montrose end of the main tunnel, in the fall of 1901, under the superintendence of Thos. R. Hannihan. The formation being shale, the tunnel was timbered, as the work progressed, with the expectation that when the work is completed the timbering will be replaced with a lining of concrete or brick. At the extra session of the legislature, the Governor and State Engineer were made ex-officio members of the board. No change in the management was made, and the work has progressed under the old regime. The secretary reports the following work done:

Length of tunnel driven, 835 feet; length of open cut, 50 feet; amount timbered, 350 feet; one air shaft sunk, 65 feet; one air shaft sunk, 90 feet. Five miles of wagon road have also been constructed. A detailed report of the work of the board will be submitted to the Governor.

Since the passage of the National Irrigation Act, the geological survey resumed work on the survey, and have about completed the final location, and the indications are very favorable for the work of construction being begun by the general government the coming spring or summer.

CONCERNING OUR PUBLIC HIGHWAYS.

Since this Department has been put in charge of all the road and bridge work done from the internal improvement fund it seems appropriate to say something in this report upon the subject of public highways in general. Several of the Eastern states have state highway commissioners or, like New York, a state engineer, under whom a comprehensive system of roads are planned out and large appropriations made for construction.

We do not advocate state control of roads, neither do we advocate the multiplication of offices. We are yet too poor and our country too sparsely settled to enter upon any extravagant or expensive era of road building. But it is believed that some plan might be worked out by which this Department could co-operate with the different counties very profitably and at little expense to the state.

Our present system of flimsy construction, characteristic of all new countries, was especially excusable in a state like ours, having long stretches of uninhabited mountainous country, through which roads had to be built to connect settlements in isolated valleys or mining camps. But we have now advanced sufficiently in wealth and population to inaugurate a new policy. The configuration of the country is such that road systems should be planned out with reference to sections embracing more than one county. Counties should co-operate with each other and with the state in the planning of the main thoroughfares connecting different sections of the state, especially in the mountainous sections. A start has been made in this direction by the passage of the Taylor State Road Bill. A more intelligent distribution of the internal improvement fund could be made and appropriations be made from year to year to build up these main thoroughfares in a systematic way.

The individual counties could take care of the less important lines.

We repeat that the time has come, we think, to inaugurate a new policy, and at this point we wish to venture a

few suggestions on road construction. More care should be shown in locations where roads are to be permanent. It will pay to hire the services of a competent road engineer in most instances. More care should be shown in the location and construction of the culverts and small bridges, as well as large ones. At least a part of the county funds should be put into permanent work each year. We believe a bill making such a proviso was introduced into the last legislature by Senator Ammons, but failed to pass. In this age of concrete, many small bridges and culverts that are now built of lumber could be built of concrete, or steel and concrete. In most cases for concrete work all the material, except cement, is close at hand, and the difference of cost between the permanent structure and the flimsy one is surprisingly small.

Of course, we can not afford expensive road construction, in the way of macadam roads, neither do we need it in this dry country. What we need is to put our roads on the proper grade; to give them proper protection from wash by storm waters, and in the valley and prairie countries to grade them up, so as to give them drainage and provide necessary culverts. In this country of irrigating ditches many unsightly "humps" are seen in the roads where laterals cross them at a grade higher than the general level of the road. This should be remedied by siphoning the water under the road. Some will say this is not practicable, on account of the filling in of such conduits with weeds, but, we think, with proper construction and proper care, the plan can be worked successfully.

We especially recommend that more care be taken in the grading of the roads in our most thickly settled districts, as we believe the time is not far distant when a system of road sprinkling may be adopted similar to that practiced in the most densely populated valleys of California. We quote here from a paper upon the subject, read before a state convention of supervisors at Fresno, in 1900, which we obtained through the courtesy of H. S. Foote, clerk of the board of supervisors of Santa Clara county:

The matter of watering our public roads, as a measure for their preservation, as well as convenience and comfort in traveling, is no longer a question for argument. In Santa Clara county it has been demonstrated by practical experiments extending over a period of more than fifteen years, that, wherever water can be obtained, there is no more economical method of keeping roads in good repair than by sprinkling them. In speaking of the economical side of the question I am referring solely to "good" roads. No amount of sprinkling can transform a poor road into a

good road. But, when a road has been properly constructed, it can be maintained in good condition by the judicious application of water more cheaply and satisfactorily than in any other manner that has, as yet, been demonstrated.

The people of this state generally consider sprinkled roads to be a luxury beyond the reach of any but very wealthy communities. This impression comes, mainly, from the fact that people estimate the expense at too high a figure and the value received at much less than it really is. Comfort in traveling is worth a great deal, but comfort is not the only thing accomplished by good roads. Economy in the power necessary to propel loaded vehicles means a saving of money in horse flesh, saving of money in the cost of feeding, a saving of money in the diminished wear of vehicles, and a saving of money in the time and labor saved in transportation. In Santa Clara county, as well as in many other fruit growing counties of the state, there is an additional source of revenue in good roads properly sprinkled. It makes it possible to deliver the products of the orchards to any cannery, factory or packing house within the county, without being bruised by jolting over rough roads in transit, or becoming foul with the dust for which unsprinkled roads in California are notorious during the season of the year in which our fruit harvest occurs. The ability to do this puts as much money into the pockets of the taxpayers as the expense of sprinkling takes out. These facts are so generally recognized in Santa Clara county that the sprinkling of our public highways is no longer considered a luxury, but as a money saving investment of the public funds.

From this paper it is learned that Santa Clara county sprinkled in 1899 350 miles of road at a cost of $80.40 per mile for the season, and this included an item of $7,158, paid for water. It is hardly likely that such an item of expense would enter into the account here. In Fresno, California, a machine is in operation (see illustration) which gathers the water from a ditch at the road side as the team is driven along in the operation of sprinkling. We believe such a machine could be operated very economically on many of the valley roads in our state.

In conclusion, we wish to call attention to Farmers' Bulletin No. 136, by Maurice O. Eldridge, on "Earth Roads," issued by the office of Public Road Inquiries, Department of Agriculture, Washington, D. C. We also wish to call attention to an article in the year book of the Department of Agriculture for 1901, by James W. Abbott, special agent Rocky Mountain Division, Office Public Road Inquiries, entitled, "Mountain Roads as a Source of Revenue." We think the perusal of that article will stimulate our people to greater efforts in the improvement of our mountain roads.

CHAPTER III.

ABSTRACT OF SUPREME COURT DECISIONS.

In the two last biennial reports the decisions of the Supreme Court relative to irrigation matters have been published and the same having been found very convenient and as supplementing the published statutes of each legislature it was deemed advisable to continue their publication.

Two years ago the 26th Colorado was the latest volume issued. Since that time the decisions already given in the biennial report have been published and are to be found as follows:

Lower Latham Ditch Co. vs. Louden Irrigating Canal Co. et al., 27 Colorado, page 267.

Wright vs. Platte Valley Irrigation Co., 27 Colorado, page 322.

New Loveland and Greeley Irrigation and Land Co. vs. Consolidated Home Supply Ditch and Reservoir Co., 27 Colorado, page 521.

Cache La Poudre Res. Co. vs. Water Supply & Storage Co. et al., 27 Colo., page 532.

Handy Ditch Co. vs. Louden Irrigating Canal Co., 27 Colo., page 515.

DE LONG ET AL. VS. PATTERSON, RECEIVER OF THE COLORADO SECURITIES COMPANY.

27 Colo., page 30.

Conveyances: Whether or not a deed to land conveys a water right used upon such land depends upon the intention of the grantor to be determined from the terms of the deed or when the deed is silent as to such water right, from the circumstances surrounding the transactions.

CRIPPEN-LAWRENCE CO. VS. BURROUGHS ET AL.

27 Colorado, page 155.

Section 2425, Mills' Annotated Statutes, providing that the court in which adjudication of water rights is had may

order a reargument or review of such decree contemplates that good cause must be shown therefor and a petition for such review must state facts from which it appears that the party applying therefor has been aggrieved by the decree. It is not sufficient to state mere conclusions in the petition. Where a party petitions for a review and relies therefor on a statutory grant he must show that the lands in question are the same as those mentioned in the statute.

LAMSON ET AL. VS. VAILES ET AL.

27 Colorado, page 201.

The courts of this state have no jurisdiction to award priorities to the use of water to a ditch intended to water lands outside the state, although the ditch has its headgate within the state.

Where a referee in a proceeding to adjudicate priorities recommended an award of twelve cubic feet to a ditch which the court reduced to four, and it does not appear why the court made such change, and the evidence is too indefinite to enable the Supreeme Court to determine from it the quantity of water the ditch should have, the case will be reversed and remanded, with instructions to the trial court to proceed upon the evidence as may be offered to determine the qutntity of water the ditch is entitled to.

UPPER PLATTE & BEAVER CANAL CO. VS. THE FORT MORGAN RES. & IRR. CO. ET AL.

27 Colorado, page 214.

The method of taking appeals from proceedings adjudicating water rights is regulated by section 2427, M. A. S., and not by code. An appeal may be taken within two years from the time the decree is rendered, but not afterward.

THE RIO GRANDE CANAL CO. ET AL. VS. THE PRAIRIE DITCH CO. ET AL.

27 Colorado, page 225.

A petition of review of a decree adjudicating priorities that contains only general allegations and conclusions of law is insufficient to justify a review of such decree where it appears that a review of a decree adjudicating water rights was reopened under section 2425, M. A. S., and a new decree rendered upon the ground that some of the parties had not complied with section 2265, M. A. S., requiring a map and

statement of ditch to be filed, the new decree will be reversed as said statute is void and unconstitutional.

Parties can not be heard to object that due diligence was not used in the construction of a ditch when the ditch was completed and water applied to a beneficial use before the objecting parties began the construction of their ditches.

CITY OF DURANGO VS. CHAPMAN.

27 Colorado, page 169.

Under subdivision 68 of section 4403, M. A. S., empowering a municipality to protect the water of streams from from which its water supply is derived from pollution, a city or town has authority by ordinance to prohibit the keeping of any pigsty or slaughterhouse upon or near the streams, the drainage from which is capable of contaminating the water even though such pigsty or slaughterhouse is well kept for such a place.

BUCKERS IRRIGATION, MILLING AND IMPROVEMENT CO. VS. THE PLATTE VALLEY IRR. CO.

Where an appeal from a judgment decreeing to junior appropriators a prior right to the waters of a tributary stream on the ground that they had largely increased the flow of such stream by the drainage of adjacent lands, the appellate court sustained the lower court to the extent that such junior appropriations were entitled to the increase of the water they had caused to flow in the streams, but reversed the judgment because it decreed them all the water in the streams instead of only the increase, and the cause was remanded for a new trial. On a second trial no finding of fact made by the lower court on the former trial or which the appellate court said was supported by the evidence, was res judicata of any fact upon which the rights of the parties to the water of such stream depended.

GRAND VALLEY IRR. CO. VS. LESHER.

28 Colorado, page 273.

Where a ditch company had issued certain certificates for perpetual water rights and recognized the transfer thereof without requiring a surrender of said certificates or their transfer on the books of the company, it waived that requirement and a subsequent purchaser under a deed expressly reserving said certificates can not object to such transfers.

A perpetual right to have a certain quantity of water flow through an irrigating ditch is an easement in the ditch.

CRIPPEN VS. WHITE ET AL.

28 Colorado, page 298.

The act of 1861, adopting the common law, was limited to the extent that it was applicable to our conditions. The law of necessity rendered the common law doctrine of riparian rights wholly inapplicable, so, that notwithstanding the declaration of the statute it has never been recognized as controlling in the matter of water rights. Owners of priority of rights to divert water from a stream are not owners of water in the stream so as to maintain an action for partition of the water of the stream.

THE HECTOR MINING CO. VS. THE VALLEY VIEW MINING CO.

28th Colorado, page 315.

When plaintiff claimed an appropriation of water from two creeks, and the point of diversion was from one creek above the point of confluence, but before defendant's rights had attached he built a dam on the other creek and a ditch therefrom, through which he causes the water to flow from the second creek into the first, above the point of diversion, and thence into and through a ditch to the point of use, it was an appropriation of water from both creeks, and a cessation of the use of the ditch between the two creeks, without an intention to abandon, was not an abandonment of the waters of the second creek.

And where defendants subsequently constructed a ditch above plaintiffs, by which they conducted water from the second to the first creek, and thence to their mills, and after its use turned the water of both creeks back into the first, so as to run down to plaintiff in sufficient quantity to support its appropriation, plaintiff was not required to keep up its ditch between the two creeks, or to take water directly from the second in order to preserve its priority right thereto.

MURRAY VS. BOARD OF COUNTY COMMISSIONERS OF MONTROSE COUNTY.

28th Colorado, page 427.

Where a ditch company conveyed to the consumers under the ditch water rights by deeds which vested in them the right

to the perpetual use of a certain amount of water, and with a proviso that when the company had sold water rights to the extent of the carrying capacity of the ditch, the ditch system should be turned over to holders of rights, so long as the company retains an interest in the ditch with water rights unsold it is not exempt from taxation.

KING VS. ACKROYD.

28th Colorado, page 488.

Where a water right is used in irrigating land, it will pass with a conveyance of the land under the word "appurtenances," without any specific conveyance, where it appears it was the intention of the grantor that it should pass.

Where a party conveyed a priority of right to the use of water, he retaining the right of a junior appropriator, and the land originally irrigated by his grantee with water conveyed becomes saturated and boggy, so that the water could no longer be beneficially used, the grantee or his successor in title can transfer the water to other lands, or to other persons in exchange for water from another ditch if, by the transfer or exchange, no more water was used than was originally used, and no other junior right was injuriously affected.

MEDINO DITCH CO. VS. ADAMS HUDSON ET AL.

68 Pacific Reporter, page 431.

Defendant appropriated water from a stream claimed as source of streams from which he claimed prior appropriations. The stream from which defendant took water flowed southwesterly until intercepted by sand hills, where it disappeared in the direction of sources of plaintiff's streams. Plaintiff took water on westerly side of the sand hills, three and seven miles from where defendant's stream disappeared. Witnesses testified to the former existence of a well-defined channel, now covered by the sand hills. The flow and character of the water in defendant's stream were reflected in plaintiff's stream, and there was no other source from which such streams could reasonably be presumed to have been supplied.

Held: Sufficient to sustain a finding that the stream from which defendant appropriated water was the source of plaintiff's streams, and the rights of priority would apply.

CHAPMAN VS. BOARD OF COUNTY COMMISSIONERS OF PHILLIPS COUNTY, IN COURT OF APPEALS.

68 Pacific Reporter, page 134.

A county is not shown to be within an irrigation district so as to make it liable for its pro rata share of the salary and expenses of the division superintendent when no lands are shown to be irrigated from streams or their tribuatries within the county.

CHEW VS. FREMONT COUNTY.

In this case it was contended by Fremont county that all counties embraced within the Arkansas water shed, whether or not they contained irrigated lands, should pay their proportion of Superintendent Chew's salary and expenses.

There are nineteen counties on the Arkansas drainage, but twelve of which had decreed ditches and used water for irrigation. It was held that among the twelve counties alone should the superintendent's salary and expenses be divided.

While the decision makes clear and emphatic the liability of the counties, it appears to limit it to those in which there are decreed ditches.

MABEE VS. PLATTE LAND CO.

In Court of Appeals, 68 Pacific Reports, page 1058.

Plaintiff owned land near the terminus of the canal of an irrigation company, together with water rights from said company. At times the canal overflowed, the excess of water running through defendant's land, who had been informed by the company that it made no claim thereto.

Defendants thereupon constructed a ditch to divert such surplus water, and to increase the overflow and surplus, obstructed plaintiff's lateral ditches. Held, that defendants had no right to any water except such as overflowed after the customers of the irrigation company had been supplied, and the obstruction of plaintiff's laterals should be enjoined.

RANDALL VS. ROCKY FORD DITCH.

68 Pacific Reporter, page 240.

Under Mills' Annotated Statutes, section 2427, providing that parties representing any ditch may appeal from a decree

establishing water rights which affects them, the right of appeal is given only to the owner or one controlling a ditch, and not to the individual consumers, and the fact that an appeal by the owner was ineffectual because of failure to comply with the statute, does not authorize an appeal by consumers of water.

NEW CACHE LA POUDRE IRRIGATION CO. VS. WATER SUPPLY AND STORAGE CO.

68 Pacific Reporter, page 781.

This case was reversed for the reasons: That sections one and two of the act approved April 6, 1899 (Session Laws, 1899, page 235), had not been complied with, which act was declared constitutional; and that "though the owner of a water right has, as an incident of the ownership, the right to change the point of diversion and of use, provided, always, the rights of others are not injuriously affected, still it is a lawful exercise of legislative power to require as a condition precedent to such changes that the person desiring them shall obtain a decree of the proper court allowing them, upon a hearing in accordance with the procedure prescribed by this act, and after a judicial ascertainment is had, that the rights of other appropriators are not injuriously affected, though such qualified right to the changes existed before the passage of the act unincumbered by the requirement of securing judicial authority therefor."

"A moment's consideration will show the wisdom of and the sufficiency of this statute, even as to vested rights. Under the original decree the water commissioner is required to distribute the water as the decree requires. It was a salutary provision for the legislature to require that the party desiring a change should, in a procedure where all the parties affected might be heard, obtain a judicial ascertainment that the change would not injure them.

"The interests of the state are involved and its rights should be protected, and parties may not render nugatory a statute whose objects *inter alia* are to protect public officers, to preserve the peace, and avoid a multiplicity of suits. Doubtless the general assembly had in view the desirability of relieving the executive officers of the necessity of determining for themselves the right of parties to make such changes as are contemplated here."

CUPPEN VS. COMSTOCK ET AL.

66 Pacific Reporter, page 1074.

An irrigation ditch which was not constructed at the time a deed of trust of land was executed and was not specifically mentioned in such deed is not conveyed thereby.

A water right, though it may be appurtenant to land, is the subject of property, and may be conveyed with or without the land.

CHAPTER IV.

REPORTS OF SUPERINTENDENTS OF IRRIGATION AND WATER COMMISSIONERS, AND CROP STATISTICS.

Heretofore this office has attempted to collect crop statistics and a record of the ditches, their length, flow capacity, etc., by sending out blanks in which was included the following items: Name of ditch, order of priority, length in miles, number of days water was carried, average amount of water carried, number of acres which were to be irrigated, number of acres of alfalfa irrigated, number of acres of grass other than alfalfa, number of acres of natural grass, number of acres of fruits, number of acres of other crops, number of acres of seepage, cost of superintendence and cost of repairs.

It has been almost impossible to obtain a complete and satisfactory report from the water commissioners. The county commissioners in many instances refusing to pay the commissioner for the time spent in furnishing this information; the commissioners were careless in giving data where it interfered with the discharge of their regular duties; the ditch owners and farmers seemed to have a fear that in some manner unknown to them the information might some day be used against them; that the county assessor might see it; that prospective purchasers might see it; that a record might be made of the amount of water used, which might possibly prevent them at some later day from enlarging their ditch and claiming more water or making use of their excessive decrees. It was therefore concluded that as much information as possible should be gathered by the commissioner himself in his daily rounds over the district; the farmer was impressed with the importance of such records, of the good which they would do him, and the county commissioners were informed that these duties were required by law and the water commissioner could neither avoid the performance of the duty as required nor the county commissioners avoid the payment

for his services. The most important information was thought to be a record of the flow of water in the ditches. Heretofore an average of the flow alone was given. It was found that this really meant nothing; that it was so indefinite as to be without value; an average of 25 feet for this season might mean 25 feet for 180 days or it might mean 500 feet for a certain period and one foot for a certain other period, which would give no idea of the capacity of the ditch or the maximum amount of water used, or the amount necessary for the land irrigated. It was thought that if a fair record of the flow of the ditch was kept, the information would be definite, would fix the quantity of water used, from which an average could be calculated; would show what season of the year the most water was used; would indicate the time of year of the increased flow of the streams, and give in connection with the acreage irrigated the duty of water under that canal.

A field book was therefore designed, in the form presented herewith. It contains some fifty pages and was intended to supply the commissioners with the means of keeping a daily record. Full instructions were set forth, the objects and the method of handling the book was printed on the first page.

INSTRUCTIONS.

Two of these books are furnished each commissioner each season for use during the season only. One is intended to be used in the field and carried by the commissioner while performing his duties. He is expected to enter in it at once each event as it occurs, so that at the end of the season it may be a complete and continuous record of the work done. It is retained by the commissioner and turned over to his successor for reference, and for the use of any one interested. It should be carefully preserved.

In the other the records are to be copied neatly in ink, which, when filed in this office, will become a part of the permanent records of the district, and will take the place of the crop reports filed heretofore. The index page may be filled out at the beginning of the season and is practically permanent from year to year. In the main body of the book one page is devoted to each ditch, and when a ditch is visited or the amount of water running into it is changed, the date and amount of water is noted in the columns provided therefor; when the ditch is dry, that fact should be noted. If thought best a daily record can be kept; in that case probably more than one page will be necessary, but if each change is noted, the flow following and until another change is made, can be taken as permanent; thus, if on June 6 forty-eight cubic feet is reported, and no other notation made until June 10, it will be evident that the forty-eight feet flow continued until June 10, when the change is noted.

In the column on remarks, note such facts as the ditch breaking, the use of reservoir water, the exchange of water, and any matters not included under regular headings.

The crop report columns scarcely need explanations, except that the blank lines can be used for any special product, such as melons, onions, winter wheat or any crop peculiar to that particular ditch.

The amount stored in or used from reservoirs may be given in cubic feet or in acre feet, whichever is most convenient. An acre foot is 43,560 cubic feet and will cover an area one foot deep. A reservoir covering one hundred acres, with an average depth of ten feet, would contain one thousand acre feet, or 43,560,000 cubic feet.

The crop statistics should be gathered as early as possible by inquiry of ditch superintendents, managers, farmers and others. In most cases these persons, if asked early in the season, will ascertain the facts for you, and by interesting them in the matter you will materially lighten your own labor. The great difficulty experienced in obtaining the necessary information is that the ditch riders and superintendents are not asked early in the season to give this information, and as a consequence have not the time to ascertain it, if, indeed, they have not already completed the season's active work and are engaged in other pursuits.

It is very essential that the 1902 books be returned to the superintendent by October 1, even should your records be incomplete, as nothing received after that date can appear in the biennial report of the State Engineer's office.

The time of the commissioner and his deputies should be kept separately on the pages provided for that purpose.

The blank pages are to be used for rating tables and for your written report to the superintendent, giving a resume of the year's work and other items of interest. The contents of the book are to be sworn to before a notary, for which a blank is provided. Look the book over carefully, and if not thoroughly understood, ask for further instruction from your superintendent.

INDEX.

Name of Ditch or Reservoir	Page	Length in Miles	Priority No.	Maximum Capacity	When Rated	Page

______________________________Ditch or Reservoir

From______________________________River.

Date	Am't of Water in Ditch	Date	Am't of Water in Ditch	Remarks

Kind of Crop	Acres
Alfalfa	
Natural Grass	
Grain	
Fruit	
Potatoes	
Garden Beets	
Miscellaneous	
Total Irrigated	
Total under Ditch	
Cost of Repairs	
Cost of Maintenance	
Amount Stored in Reservoirs from Ditch	
Amount Used from Resvoirs by Ditch	

After one season's experience the book is not exactly what it should be, and does not meet the requirements of all the districts. In most districts, however, it has been found to work very satisfactorily, where the commissioner had the inclination and the intelligence to properly fill out the blanks. The records obtained from these books are much more complete and satisfactory than those heretofore given, although the commissioners had some difficulty in understanding at first just what was required. After this year's experience and instructions there should be little difficulty in obtaining most complete and excellent records. The point particularly to be insisted upon during the coming season should be that these books be carried into the field, and that records be made each day, and at the time of their occurrence.

It might be well to increase the number of spaces for record of the amount of water in each ditch, so that a daily record could be kept, or to make a double column of dates which would show the period during which a certain amount of water was run.

The crop statistics might be altered somewhat. In some sections the special crop is potatoes; in others it is beets; in others still it is onions or cabbage. A record of these special crops should be kept. The result achieved is such as to give great encouragement, and we believe the field book to be a good innovation.

In the tables which follow it will be noticed that in some districts there is a decrease of acreage in some or all of the crops. This decrease arises from the fact that in the commissioner's reports only such ditches as were visited were reported—leaving, in some cases, whole sections unreported. Notwithstanding this, however, it will be seen there is quite an increase, and development appears to be active.

SUMMARY OF DITCH AND CROP REPORTS FOR 1901.

Division No.	Length of Ditches, in Miles	Area actually Irrigated	Maximum Amount Water carried during season of 1901, in Second-Feet	Number of Acres that can be Irrigated	Number of Acres of Alfalfa Irrigated	Number of Acres of Seeded Grasses, other than Alfalfa, Irrigated	Number of Acres of Natural Grasses Irrigated	Number of Acres of Fruits Irrigated	Number of Acres of Other Crops Irrigated	Number of Acres Irrigated from Seepage
1	2,884	877,457	7,487	1,022,208	212,839	128,743	189,046	22,296	424,533	5,859
2	2,249	346,812	18,225	552,644	140,165	7,060	44,274	13,853	105,699	4,352
3	1,443	398,472	4,651	609,939	9,286	....	186,863	1	197,176	3,600
4	879	48,918	786	123,212	19,971	2,441	3,209	....	19,313	....
5*	1,348	113,696	1,409	256,809	51,102	10,843	12,095	9,929	28,251	1,476
6	515	63 629	1,387	84,900	14,769	28,928	12,786	8	6,963	75
Totals	9,318	1,868,984	33,945	2,649,712	448,132	78,015	448,273	46,087	781,935	15,362

*From report of 1899.

SUMMARY OF DITCH AND CROP REPORTS FOR 1902.

Division No.	Length of Ditches, in Miles	Area actually Irrigated	Maximum Amount of Water carried during Season of 1902, in Second-Feet	Number of Acres that can be Irrigated	Number of Acres of Alfalfa Irrigated	Number of Acres of Seeded Grasses, other than Alfalfa, Irrigated	Number of Acres of Fruits Irrigated	Number of Acres of Other Crops Irrigated
1	3,105	743,375	19,277	1,081,284	193,949	176,724	19,647	358,535
2	4,774	297,668	18,533	606,748	125,221	42,843	11,936	61,251
3	1,031	157,551	6,495	375,688	....	....	....	12,537
4	680	48,021	690	59,410	17,661	5,804	....	28,496
5	1,501	271,245	2,043	314,113	64,887	20,334	10,220	26,520
6	435	68,688	1,426	77,660	15,713	44,845	8	8,109
Totals	11,526	1,586,548	48,464	2,514,903	417,431	290,550	41,811	495,448

SUPERINTENDENT OF IRRIGATION.

DIVISION NO. 1.

Denver, Colo., November 26, 1902.

HON. ADDISON J. MCCUNE,
State Engineer, Colorado.

Dear Sir: In submitting this, my annual report of the operations of the irrigation department in Division No. 1, I wish to make some remarks on the workings of our irrigation laws and the effects thereof on the service of this office, and also on the interests of the farmers and ditch owners in the different districts in this division.

In the first place, the past season will go on record as the dryest year that Colorado has known since irrigation has been practiced in the state, and, while the lack of rains added to the great scarcity of water, has been very injurious to the farming interests, it has also been a fruitful cause of litigation by bringing up questions of priority and the proper use of priorities, which were never before thought of.

It is becoming understood that the value of water for irrigation is very much above the price that has been set upon it, consequently, the very best legal talent is being employed to secure the right to use the water by junior appropriators, very often to the injury of older and senior appropriators. A favorite procedure in this line of action is in obtaining the issuance from the county courts of a writ of temporary injunction, restraining the officers of the irrigation department from enforcing the laws made and provided for the proper distribution of water for irrigation purposes. Especially is this true where the interests of one irrigation district come into conflict with those of another. This office has been seriously embarrassed in the performance of its duties during the past season by this trick, for it is a trick, although a legal one, whereby a canal company, or district, can hold the water to which they are not entitled for a period of time, and, when a hearing is had, ask for a dismissal of complaint and the dissolution of the injunction on payment

of costs, which they can well afford to pay. I would suggest that something be done to remedy this, either by the coming legislature, or by a ruling of the Supreme Court on an agreed case covering this question.

The right of old canals to extend and enlarge their capacity, so as to enable them to appropriate and take from the streams the full amount of water decreed to them of a date twenty or thirty years ago, and apply such water to a territory recently brought under cultivation; also the right to sell and transfer to new ditches the surplus portion of decrees granted to old ditches, but never appropriated and used by them, to the injury of intermediate appropriators, are questions which should be settled, so that the old appropriators and prospective investors in irrigation enterprises may know on what ground they stand in this line.

The past season has again demonstrated the great importance of the storage reservoirs that are in operation in the northern section of this division, as under all those ditches that have been supplied with water for late irrigation from this source, the yield of all crops has been fully up to the average, while under those ditches which have been without this supply, the yield has fallen far below, and in some instances has been an almost total failure.

There has been, in this division, during the past season, about 12,000 acres of land devoted to the cultivation of the sugar beet, with a prospect of double or treble the amount next year, and nearly as much land is given to the raising of potatoes. Products such as cabbages, onions, and other vegetables, and fruits, are cultivated quite as extensively; also alfalfa, which is required for the success of the stock-raising and sheep-feeding industries, is of equal importance. All these need water for late irrigation, still further emphasizing the necessity of saving all the available water in storage reservoirs, and also convincing us of the necessity of protecting and saving our forests, which are the natural mountain reservoirs. The greatest efforts in this direction are imperative, and should be made by every citizen, irrespective of his occupation.

This office has received tabulated reports from all of the district commissioners in Water Division No. 1, and reports from eight of them, giving detailed accounts of operations in their several districts. With your permission, these are made a part of this report. These reports, with the the exception of those from three irrigation districts, Nos. 46, 47 and 48,

North Park, all tell the same story of great scarcity of water. In these districts, however, the only use made of the water is for the irrigation of hay lands, and the supply has proved amply sufficient.

A summary of these tabulated reports shows a length of ditches in this division of 3,105.01 miles. A maximum capacity of ditches and water carried of 19,267.71 cubic feet per second time. The highest number of days water was carried being 321.

The number of acres that can be irrigated	1,038,284
The number of acres that can be actually irrigated	743,375
The number of acres of alfalfa	193,949
The number of acres of grasses	176,724
The number of acres of grain	216,504
The number of acres of fruit	19,647
The number of acres of beets	11,480
The number of acres of potatoes	6,981
The number of acres of other crops	123,569

The reports of expenses for maintenance are neither full or satisfactory, seven of the commissioners making no report of this matter. The reports of the other eight commissioners foot up a total of $130,356.65. For further information as to the operations of the commissioners in their respective districts you are respectfully referred to their reports, which are herewith submitted.

I wish to again call attention to the very unsatisfactory manner in which these reports are collected, and can only say that the means provided therefor are entirely unsatisfactory.

In closing, I wish to express my thanks to all the officers and employes of the Department for the uniform kindness and courtesy extended to me during the past years.

Respectfully submitted,

JAMES J. ARMSTRONG,
Superintendent Irrigation Division No. 1, Colorado.

SUMMARY OF COMMISSIONER'S REPORTS, A. D. 1901.

JAMES J. ARMSTRONG, SUPERINTENDENT DIVISION NO. 1.

District No.	Length of Ditches, in Miles	Number of Days Water Was Carried There-in	Average Amount of Water carried during Season of 1901 in Second-Feet	Number of Acres that can be Irrigated	Number of Acres of Alfalfa Irrigated	Number of Acres of Seeded Grasses, other than Alfalfa, Irrigated	Number of Acres of Natural Grasses Irrigated	Number of Acres of Fruits Irrigated	Number of Acres of other Crops Irrigated	Number of Acres Irrigated from Seepage
1	194	200	642	83,110	18.100	115	15,955	176	37,670	150
2	319	245	1,177	85,176	26.197	192	7,984	438	33,829	407
3	396	365	1,578	202,015	53,995	958	7,887	2,012	123.026	2,065
4	217	132	426	77,818	20,325	725	2,350	2,240	45,975	2,825
5	266	250	612	91.795	8,025	3,200	20,085	1,590	55,910	....
6	238	200	502	87,342	18,489	4,623	9,815	2,314	43,871	1,325
7	251	220	474	147,307	34,545	12,685	2,825	11,895	52,593	1,930
8	148	205	547	36,630	12,165	1,700	1,220	1,330	20,045	....
9	69	200	79	14,873	4,702	1,415	567	337	5,083	957
23	311	93	359	67,213	....	....	67,143	....	36	....
46	147	....	206	13,865	....	770	13,075	....	....	....
47	98	100	268	32,190	....	1,550	15,730	....	....	....
48	35	98	164	5,625	....	....	4,230	....	....	....

64	152	210	422	74,400	15,566	10	19,890	64	5,405	200
65	43	180	31	2,849	730	....	290	....	1,090	....
Totals	2,884	365	7,487	1,022,208	212,839	28,743	189,046	22,296	424,533	5,859

SUMMARY OF COMMISSIONER'S REPORTS, A. D. 1902.

JAMES J. ARMSTRONG, SUPERINTENDENT DIVISION NO. 1.

District No.	Length of Ditches, in Miles	Maximum Amount of Water Carried	Number of Acres of Alfalfa	Number of Acres of Grass	Number of Acres of Grain	Number of Acres of Fruit	Number of Acres of Potatoes	Number of Acres of Beets	Number of Acres of Miscellaneous Crops	Number of Acres Actually Irrigated	Number of Acres under Ditch
1	188	1,650	15,885	12,996	8,820	52	56	500	28,210	66,519	136,519
2	342	2,613	27,748	7,530	2,590	304	100	410	33,042	60,785	75,181
3	344	2,577	46,060	9,013	35,456	1,536	40	1,060	43,925	97,910	189,720
4	203	1,586	19,875	2,765	56,210	2,065	4,045	6,008	580	91,548	91,548
5	250	770	13,250	20 290	32,829	1,420	2,293	1,070	2,078	83,201	100,160
6	376	285	14,815	9,285	36,665	2,555	237	645	3,596	102,818	102,818
7	270	1,213	26,770	13,750	29,610	10 340	150	1,770	10,348	94,943	152,723
8	155	906	5,165	1,075	5,345	1,035	....	....	508	13,128	13,128
9	62	268	4,911	1,555	4,537	252	....	13	67	11,171	13,052
23	327	4,328	....	32,385	....	....	....	....	....	32,385	40,000
46	109	402	....	21,190	....	....	....	....	....	20,820	21,160
47	87	629	....	19,469	....	....	1	....	....	19,875	27,157
48	48	323	....	1,810	1	1	....	....	....	2,638	4,175

64	344	1,727	18,740	22,696	2,326	88	43	....	1,175	43,643	110,950
65	....	....	730	915	295	....	16	5	40	2,061	3,000
Totals	3,105	19,277	193,949	176,724	216,504	19,648	6,981	11,481	123,569	743,375	1,081,284

REPORT OF SUPERINTENDENT OF IRRIGATION.

WATER DIVISION NO. TWO.

Dear Sir—In my former reports I have described Water Division No. 2, which embraces all that portion of Colorado irrigated by waters of the Arkansas river and its tributaries.

There are more than one-half million acres lying under the three thousand three hundred and seventeen miles of irrigating ditches in the valley.

The development is due almost exclusively to private and community enterprise. About a hundred thousand acres are in grain and the same amount in alfalfa. There are about twenty thousand acres in fruits and twenty thousand in sugar beets—the latter developed within the last four years. Too much can not be said of the sugar beet industry, which has assumed almost the first place among the agricultural industries of this portion of the state. During the last year the output of the sugar factories at Rocky Ford and Sugar City were by more than twenty-five per cent. greater than any previous year, and it is probable that another factory will be located at some other point in the valley before long, as the product is rapidly approaching the limit of capacity of the present factories.

It may be interesting to know something of the cost of raising and delivering beets to the factory in this section. The following estimate has been compiled after careful study of the conditions here. The expenses are as follows:

Rent of land per acre	$ 5 00
Preparing land	2 50
One winter irrigation	50
Three summer irrigations	75
Harrowing, three times	75
Seed	3 00
Seeding	35
Cultivating, five times	2 50
Bunching and thinning, by contract labor	6 00
Hoeing, by contract labor	6 00
Pulling and topping, by contract labor	6 00
Plowing up beets	1 75
Hauling	5 00
Total cost, per acre	$40 10

The production per acre, where ordinary care is used, will average fifteen tons per acre, which means to the grower $75 per acre gross, or a net profit to him of $35. Beets grown by irrigation apparently contain a greater per cent. of sugar than those grown in the humid regions, the great number of hours of sunshine producing a large per cent. of sugar. The percentage of sugar in our beets is said to be not less than eighteen per cent., while the production seldom falls below ten tons per acre.

SUGAR CITY.

Less than three years ago Sugar City did not exist. It now has about 2,500 inhabitants, due almost entirely to its sugar industry. The Sugar City factory owns or controls twelve thousand acres of land, watered from the Colorado Canal, which, during the low stage of water, receives water from Henry lake and the Twin Lakes reservoir at Rocky Ford. Where a careful record is kept by each farmer, the highest amount paid for any one acre was, in 1900, $128.69, the number of tons being 26, with an average of 18.2 sugar, and of purity, 85.6. In 1901 the largest amount paid for the yield of one acre was $146.64, the number of tons being 28.4, the per cent. of sugar 19, and purity 84.85. As the entire crop has not been harvested for 1902, we have no record for this year. It is expected, however, that the average yield will exceed that of the past two years. The factory expects to produce 27,000,000 pounds. The invasion of the sugar beet has in no wise curtailed the production of cantaloupes and watermelons. It is safe to say that $350,000 was received for cantaloupes during the present season. The fruit crop in Fremont county was very fine, and conservative estimates place the value of the fruit crop at $300,000, of which two-thirds, at least, can be credited to apples.

The grain crop during the past season is probably considerably below the average. The acreage is less and the weather conditions, especially in the higher plateaus, were unfavorable. Corn alone of the grains would probably exceed the average yield.

The yield of alfalfa also is probably less than usual, owing to the fact that many alfalfa fields have been broken up and put into beets and cantaloupes.

The market gardens of this district are quite important, considerable of the product being shipped to the mountain towns tributary to the valley. The production of honey is

enormous and may amount this year to $100,000. In quality, the product is unexcelled.

The large amount of unoccupied land in the valley affords finest summer and winter food for stock, while the alfalfa, corn and beet pulp supply food for fattening cattle. Not less than twelve thousand head will be fattened at the sugar factories by Colonel Lockhard and the Nuckolls Packing house.

The canning factories have increased their outputs and are in a very prosperous condition.

The subject of reservoirs in the arid regions is one upon which volumes could be written, and then the half of what should be generally known would not be told.

The experiences of the season of 1902, through which we have just passed, have abundantly demonstrated the great value of storage reservoirs. Without stored water, agriculture in the Arkansas valley would have been almost a failure during the past season.

The construction of good storage reservoirs is the key to the irrigation problem. For many reasons mountain reservoirs are generally superior to those constructed on the plains. Mountain reservoirs are more easily filled with water and, as a rule, are in less danger from cloudbursts; they are less likely to be filled with silt and debris than are the reservoirs of the plains, and the losses of water by seepage and evaporation therefrom are not nearly so great as are such losses from reservoirs in the low altitudes. Under ordinary conditions, mountain reservoirs are quite likely to be filled with water each year if the drainage areas from which they are supplied are reasonably large.

The best demonstration afforded in the Arkansas valley of the value of a mountain reservoir, is that wonderful storage basin known as the Twin Lakes reservoir, situated high in the mountains on one of the important tributaries of the Arkansas river. During five days in May, when the order had gone forth permitting the storage of water in reservoirs, this reservoir impounded quite five feet in depth, which covered an area of over 2,200 acres. When it is remembered that during the year just closing there were only eight days during which water could be diverted for storage in reservoirs, it will be seen how important it is that the reservoir companies should be in condition to store water on a moment's notice. During the year 1902, when the streams carried more water than was needed for immediate irrigation and hence

water available for storage, such excess of water was due to great cloudbursts. The immense volume of water in the stream channels due to cloudbursts washed out headgates and dams of some of the diverting ditches in the lower valley, so that these ditches were not available to their full capacity for the conveyance of water from the streams to the reservoirs of the plains. This was not the case with some of our mountain reservoirs, notably the Twin Lakes reservoir. As a rule, the ditches which supply our reservoirs upon the plains are not sufficiently large. This also was demonstrated this season. Upon several occasions we had from thirty thousand to forty thousand cubic feet of water per second that was absolutely lost to the irrigators in the state of Colorado, and which was wasted in the great sand beds of Kansas because the canals in Colorado conducting waters from the Arkansas river to the reservoirs of the plains were not sufficiently large to conduct these flood waters from the streams to the reservoirs during the short period of excessive flood waters.

Where the conditions exist which do exist in the Arkansas Valley, it seems to me unwise for the government to build reservoirs and construct new ditches for the irrigation of new lands until after sufficient water has been impounded to irrigate all the lands now lying under ditches and capable of being watered by the irrigation works already constructed. Today in this valley we have neither water nor reservoirs sufficient for the land already under ditches. It certainly seems better to expend our money and energy in the construction of reservoirs for supplying ditches already constructed than to expend part of that money in the construction of unnecessary ditches.

In connection with the holding back of the waters which fall upon our mountains, I personally saw demonstrated, in a small way, some twenty-three years ago, in the northwestern country, the forming of artificial ice sheets and glaciers by means of the water carried in a placer ditch; the water of this ditch was spilled on the north side of a mountain, the flow of the daytime being frozen at night.

I believe that the taking out of ditches near timber line in our valley, running the water diverted by such ditches to the north sides of the mountains, properly discharging the water so carried at different points along the line of the ditch so that it would sink into and drain down the moutain side, and as the weather grew colder freeze and continue to freeze, forming ice sheets or minature glaciers, would be a success-

ful storage method. The ice sheets or glaciers thus formed would, of course, melt as the season grew warmer and supply a continuous amount of water until late in the summer. This plan of water storage could be carried out in drainage basins not supplied with good reservoir sites.

Any plan for storing water or holding back until needed for irrigation, the waters precipitated upon our mountains, is worthy of the most earnest consideration of our people.

WATER LAWS.

The entire farming industry, together with many other industries, including the canning industry and the sugar beet industry, depend upon irrigation, and the irrigation of the lands upon which these crops are raised depends upon the ditches and the water laws governing the distribution of water. Water is distributed according to priority of appropriation, and a farmer with an early right can have water whenever he needs it. This law of priority of appropriation has been modified to some extent by statute, which recognizes the borrowing of water so that a farmer who is not entitled to water under the priority rights enjoyed by his ditch may have water for his crops if his ditch company can borrow water from some other ditch so enjoying earlier rights. That law which permits this borrowing and lending of water is one of the wisest, one of the best, ever placed upon the statute books for the good of the farmer. That this statement is true, has been thoroughly demonstracted by the experience of this season in the Arkansas Valley. The year 1902 has been one of great drought, perhaps no greater drought has been known in the history of the state; springs and streams dried up that were never known to fail before, because of the hot weather and lack of moisture. During this season hundreds of acres had to be replanted, and but for the exchange of water between ditches there would have been great damage to crops of all kinds in this valley, including the sugar beets in many localities, and thousands of acres planted to sugar beets would have been replanted to alfalfa; land prices decreasing from $100 to $200 an acre down to $35 an acre, because of such changes. No greater disaster to the Arkansas Valley could happen than a repeal of the law permitting the loaning of water by ditches. When that law was placed upon the statute books of Colorado, it did more to enrich the Arkansas Valley in Colorado than any other law, and increased the value of the lands of the valley by millions of

dollars. Too much praise can not be given framers and supporters of that law.

Acknowledging the courtesies extended this office by yourself and your assistants, and taking this opportunity to thank the water commissioners of Water Division No. 2 for their friendly and able co-operation in the work of distributing the waters of the division and of gathering irrigation statistics, I am, sir,

Very respectfully your,

E. R. CHEW,

Superintendent of Irrigation, Division No. 2.

Pueblo, Colo., November 1, 1902.

The commissioner of District No. 10 reports very little water. The Monument reservoir, built by the state, was opened May 21 at 7 p. m., reached Colorado Springs May 22, at 9 p. m. On the 23d water was given to ditches with priorities Nos. 41, 29 and 31; on May 24 to ditches Nos. 16, 27 and 50. These had water until the 26th, when a storm broke out all ditches; about three thousand acres were irrigated, however, from the reservoir. On July 26 the reservoir was again opened and on the 27th ditches Nos. 29 and 31 received water for forty-eight hours, when it was given to Nos. 15 and 27. On the 31st twelve feet was given to ditch No. 16. The reservoir water was shut off on August 2. During this run about two thousand acres were irrigated.

D. J. Houston, of District No. 13, appears to have had something of a time himself. He says on October 1: "We are still having lots of trouble about water. I will be pleased when the season comes to and end and trust it will be a long time before another such strikes this country. I am sure I have fallen out with more people this summer than in any ten years of my life, and all from trying to do right is what hurts. If I had done wrong intentionally I would have expected quarrels and dissatisfaction. However, it will soon be over and I suppose I ought to be thankful that I am alive."

T. J. Burrows, of District 14, reports that about fifty per cent. of the normal flow was in the Arkansas river at Pueblo during the year 1902. On May 26 a cloudburst on Fountain creek washed out a good many headgates and bridges. Notice given early in the spring to all ditch owners to put in headgates and rating flumes had generally been complied with. Mr. Burrows says that it is impossible to adhere strictly to

the rating tables for the various ditches on account of the constantly changing conditions of the shifting sand, deposits of silt, etc. He thinks the water commissioner should be clothed with discretion in the matter. On August 5 a cloudburst in the vicinity of Canon City caused a flood at Pueblo amounting to thirty-five thousand cubic feet (estimates in the State Engineer's office, however, reduce this amount more than twenty-five per cent). A considerable increase is reported in the acreage in sugar beets and other crops.

M. C. Goss, of District No. 15, suggests that the Attorney General should be constituted legal adviser for the water commissioners. He thinks the law requiring headgates and rating flumes is unsatisfactory and suggests that the water commissioners should put these structures in, and that the debt so created should be a lien on the ditch.

J. W. Bowman, of District No. 17, reports very low water, but extreme floods. The alfalfa crop is limited to two cuttings. The acreage in sugar beets was much greater, being about 18,000 for both factories, and the average yield, fifteen tons; canteloupe crop was the best in the history of the valley.

W. A. Garner, commissioner of District No. 19, has had considerable trouble during the past year. He reports that he had little or no water, had few lawful headgates, and no rating flumes in his district. He ordered headgates and flumes put in, but his orders were ignored. He closed the water out of the ditches by means of picks and shovels, and they were immediately opened. He appealed to the district attorney to prosecute these people. The district attorney at first believed there was no law which could reach them. Later he prosecuted one party for opening his ditch. The court decided that the decrees in the District Court were void, and that the people would be permitted to take water as they pleased. To quote Mr. Garner, he then says, "within a very few days after the court ruled that ditch decrees were void, upon petition of the city of Trinidad, the same judge and court made an order of injunction, served on ditch users to close their ditches to allow the water to pass the headgate of the city water works. This was done and the city still continues to sell water to railroad companies and to the Colorado Fuel & Iron Company, when there is no water passing below Trinidad for domestic use for people living below." Previous to this the water commissioner had ordered the city to discontinue the use of water, as their priority was such that they were not entitled to any. The mayor flatly refused to obey the laws, and the district attorney refused to prosecute. It

appears that Mr. Garner has done everything within his power to enforce the laws, and his failure has been due to a lack of support from the district attorney and from the courts. Mr. Garner further says, "the users of water do not want their ditches closed and locked; they want them left open all the time, and they are very much determined to keep them open, the requirements of the law and work of the commissioner notwithstanding. The amount of $2.50 for pay of deputies is not sufficient to secure the services of good, faithful men. Men who are competent can do better at work and business. In this district the work is very unpleasant, and also here the expenses are about as much as the pay now allowed."

George B. Wick, of District No. 67, reports a flood on May 28, estimated at 50,000 cubic feet, which carried away the headgates of the Amity and Graham canals. On June 30, July 28 and August 7, the district again suffered from floods, all causing more or less loss and damage. He reports the acreage limited to crops greater than heretofore, but the yield diminished, owing to the breaking of the Amity headgate. Mr. Wick recommends fall irrigation.

SUMMARY OF COMMISSIONER'S REPORTS, A. D. 1901.

E. R. CHEW, SUPERINTENDENT DIVISION NO. 2.

District No.	Length of Ditches in Miles	Number of Acres Actually Irrigated	Average Amount of Water carried during Season of 1901 in Second-Feet	Number of Acres that can be Irrigated	Number of Acres of Alfalfa Irrigated	Number of Acres of Seeded Grasses other than Alfalfa Irrigated	Number of Acres of Natural Grasses Irrigated	Number of Acres of Fruits Irrigated	Number of Acres of other Crops Irrigated	Number of Acres Irrigated from Seepage
10	118	14,296	226	31,930	4,315	471	5,099	404	2,803	1,204
11	427.75	26,592	1,160	58,435	4,382	2,862	9,067	1,168	8,078	1,437
12	267.50	13,195	428	16,984	5,568	879.50	2,007	2,135	3,106	1
13	100	10,053	14,809	10,971	880	1,445	4,249	....	3,479	....
14	307.25	85,019	581.61	148,737	35,875	2,158	4,155	5,050	36,466	1,315
15	175.03	7,604	....	12,599	4,177	978	836	365	1,068	180
16	221.62	9,093	296.54	15,850	3,922	264	1,117	64	3,706	....
17	273.50	95,395	892	97,400	50,110	30	9,055	1,780	34,420	....
18*	....	....	....	....	....	....	....	....	....	....
19	220.40	19,812	419.30	43,393	8,496	135	1,439	134	9,593	15
49*	....	....	....	....	....	....	....	....	....	....
66*	....	....	....	....	....	....	....	....	....	....
67	239	55,773	413	126,345	22,640	....	17,250	2,803	12,880	200
Totals	2,249.05	346,812	18,225.45	552,644	140,165	7,060.50	44,274	13,853	105,699	4,352

* No reports.

SUMMARY OF COMMISSIONER'S REPORTS, A. D. 1902.

E. R. CHEW, SUPERINTENDENT DIVISION NO. 2.

District No.	Length of Ditches, in Miles	Maximum Amount of Water Carried	Number of Acres of Alfalfa	Number of Acres of Grass	Number of Acres of Grain	Number of Acres of Fruit	Number of Acres of Potatoes	Number of Acres of Beets	Number of Acres of Miscellaneous Crops	Number of Acres Actually Irrigated	Number of Acres Under Ditch
10	111	283	1,847	5,278	2,086	384	25	65	404	13,657	32,020
11	349	888	4,136	5,324	410	106	54	200	9,253	19,508	36,153
12	176	398	6,032	1,234	2,523	2,755	6	5	1,241	13,560	15,000
13	43	45	510	1,926	952	....	2	....	....	3,385	5,845
14	2,928	2,746	29,653	4,376	6,135	4,944	100	8,320	21,441	74,412	192,870
15	191	10,165	821	85	12	160	....	....	290	1,368	9,893
16	221	300	15,426	5,884	2,840	28	....	15	2,631	26,791	33,645
17	277	2,003	44,240	8,960	17,740	2,415	20	9,570	3,940	66,340	94,270
18*	....	....	....	....	....	....	....	....	....	....	....
19	240	755	3,936	1,096	1,339	126	3	296	261	7,057	42,567
49*	....	....	....	....	....	....	....	....	....	....	....
66*	....	....	....	....	....	....	....	....	....	....	....
67	238	950	18,620	8,680	....	1,018	116*a*	3,553	21,770	63,716	145,485
Totals	4,774	18,533	125,221	42,843	34,037	11,936	326	22,024	61,251	288,994	606,748

* No reports. *a* Cantaloupes.

REPORT OF SUPERINTENDENT OF IRRIGATION.

Division No. 3.

Hooper, Colorado, January 25, 1902.

Hon. A. J. McCune,
State Engineer, Denver, Colorado.

Dear Sir—I herewith submit my report as superintendent of irrigation of Water Division No. 3, known as the Rio Grande Division, together with reports of the various district commissioners in my division, namely, districts Nos. 20, 21, 22, 24, 25, 26, 27, and 35. You will find reports of all commissioners, with the exception of John C. Dalton, of District No. 22, who refuses to make report to me, or at least pays no attention to my demands for a report. I might say here that waiting and trying to get his report is the cause of the delay in my repart.

I have experienced much difficulty in obtaining the data necessary to make such a report as, I presume, you would like to have, as it was necessary to depend exclusively upon water commissioners in the various districts, and, inasmuch as there is no provision made for the payment of services of water commissioners rendered in preparing these reports, many of them have given it very little attention. Many ditches decline absolutely to give this office any information whatever as to the cost of maintaining and operating their ditches, their excuse being the assessor might get hold of it and raise their valuation.

There has been no rating done in any of the districts in my division in 1901, but we have notified every ditch owner or operator, as required by the law passed by the last general assembly, that we would not deliver water to any ditch for the season of 1902 until they had fully complied with the law. This law is going to be a great help to commissioners in distributing water, and, in my opinion, should be enforced to the letter. We have had a case or two under the new law in regard to tampering with headgates and stealing water, and, I am sorry to say, have been beaten.

The law is not yet what it should be. However, I do not pretend to be lawyer enough to propose an amendment.

The water supply for 1901 has been the shortest known in this division for years, and especially in District No. 20, being less water passed the government measuring station at Del Norte than ever known since the station was established. The commissioners did extra well in handling the water, and did it to the satisfaction of the users, but, at the best, our crops were cut short over half.

The district irrigation and reservoir law is being agitated a great deal in this division, but there is some difficulty between our country and Mexico in regard to the rights to the waters of the Rio Grande, our main water source, that has, in a measure, discouraged our people. We would be pleased to see this case, which we understand is now in the courts, pushed to some ending.

Prospects for 1902, while not flattering, are reasonably good, as the last few days we have reports of considerable snowfall on the heads of both the Rio Grande and Conejos, which means lots of early water, if it *does not* hold out all season.

Respectfully submitted,

WESLEY STALEY.

In Division No. 3, F. W. Swanson, commissioner of District No. 20, reports that he had considerable trouble in getting measuring flumes and headgates put in. He succeeded in getting over fifty put in, which is about half of that necessary. Undecreed ditches taking water have been an annoyance, especially as it seemed impossible to secure a conviction for infractions of the law. One method of securing water was to build dams across the streams. Mr. Swanson complains that it is impossible to get good deputies for the amount allowed them for their services. He recommends that each deputy be furnished with a field book. Mr. Swanson has also had trouble in collecting his expenses and per diem from some of the counties.

Commissioner Albert, of District No. 24, says that 1902 was the dryest since 1879. The crops were not over two-thirds of the average. Three arrests were made of persons taking water illegally. It is refreshing to learn that these were convicted and fined.

J. M. Pitzer, commissioner of District No. 25, reports a serious shortage of water. He says that he practically had

to sit on the headgates in order to give the proper ditches the water belonging to them.

In Division No. 4, Louis Jarrett, of District No. 34, reports that considerable water was wasted in his district, although the supply was very limited. Considerable of his time was occupied in distributing reservoir water. He reports that two dollars and fifty cents is insufficient for the employ of a deputy. He had trouble in keeping the headgates closed, but succeeded in getting his district fairly well supplied with rating flumes and headgates. The commissioners of Dolores county notified Mr. Jarrett that he had no jurisdiction in that county.

SUMMARY OF COMMISSIONER'S REPORTS, A. D. 1901.

WESLEY STALEY, SUPERINTENDENT DIVISION NO. 3.

District No.	Length of Ditches, in Miles	Number of Days Water was Carried therein	Average amount of water carried during Season of 1901 in Second-Feet	Number of Acres that can be Irrigated therefrom	Number of Acres of Alfalfa Irrigated therefrom	Number of Acres Actually Irrigated	Number of Acres of Natural Grasses Irrigated therefrom	Number of Acres of Fruits Irrigated therefrom	Number of Acres of Other Crops Irrigated therefrom	Number of Acres Irrigated from Seepage
20	361	180	1,912	383,100	3,000	258,000	90,000	....	162,000	2,250
21	187	180	436	23,085	1,490	17,600	9,050	....	6,935	110
22*	331	180	860	106,000	1,225	32,000	14,590	....	16,000	....
24	41	200	126	10 528	519	10,528	1,772	1	8,215	440
25	238	180	900	45,000	300	44,686	44,386	....	....	....
26	180	230	231	25,666	2,346	23,658	18,591	....	2,721	....
27	26	120	18	7,960	300	2,000	840	....	65	800
35	79	100	168	18.600	106	10,000	7,634	....	1,240	....
Totals	1,443	180	4,651	609,939	9.286	398,472	186,863	1	197,176	3,600

*Estimated. No report from commissioner.

SUMMARY OF COMMISSIONER'S REPORTS, A. D. 1902.

WESLEY STALEY, SUPERINTENDENT DIVISION NO. 3.

District No.	Length of Ditches, in Miles	Maximum Amount of Water Carried	Number of Acres of Alfalfa	Number of Acres of Grass	Number of Acres of Grain	Number of Acres of Fruit	Number of Acres of Potatoes	Number of Acres of Beets	Number of Acres of Miscellaneous Crops	Number of Acres of all Crops Actually Irrigated	Number of Acres Under Ditch
20	555	4,528	4,660	53,245	23,404	42	2,671	749	12,149	96,920	297,201
21	220	1,275	2,142	15,207	4,442	21	420	10	100	22,342	32,962
22*	....	....	....	....	....	....	....	....	....	....	....
24	41	255	557	2,134	8,230	3	92	31	20	11,067	....
25	115	98	386	13,389	660	11	66	2	11	14,519	29,025
26	10	102	1,934	2,068	809	28	136	....	180	5,155	....
27*	....	....	230	1,000	40	5	18	3	7	1,303	....
35	90	237	40	4,580	1,550	....	5	....	70	6,245	16,440
Totals	1,031	6,495	9,939	91,623	39,135	110	3,408	795	12,537	157,551	375,628

* No report.

REPORT OF SUPERINTENDENT OF IRRIGATION.

Division No. 4.

November 19, 1902.

Mr. A. J. McCune:

Dear Sir—I herewith submit my final report for the seasons of 1901 and 1902. In the spring of 1901 there was plenty of snow in the hills to make sufficient water for the season, but the continuous warm rains in the early spring melted the snow earlier than usual, so that the water fell very rapidly after the rain had ceased, causing to become very low by the last of June, and after that date there was not enough water to supply one-half the ditches in the division. In the spring of 1902 there was very little snow in the hills, and the trouble over water began early in the season and continued all summer.

The districts in this division, with the exception of No. 33, are much too large for one, or even two, men to handle, some of the ditches being ninety miles apart, making it impossible for the commissioner to give satisfaction, and it is impossible to hire a capable deputy for $2.50 per day, as the expenses would eat up the salary. Then the county commissioners in some of the counties interfere with the water commissioner, threatening to cut their bills, etc., making it hard for the superintendent to get good results from the work. But I believe the water commissioners in this division have done their best to give satisfaction, and I would especially recommend Mr. Lewis Jarrett, of District No. 34. I have been treated well by the commissioners of La Plata county, but have never received one cent from either Montezuma or Archuleta counties, though I have judgments against both of them for last year's pay.

There are some of the best reservoir sites in Montezuma and Archuleta counties that can be found anywhere, but the farmers are slow in taking advantage of them, I expect, because of lack of capital.

With this I will send the last crop report received by me.

Thanking you very much for the advice and assistance you have given me from time to time,

I remain yours,

E. D. SAMAIN.

In Division No. 5, commissioner's report is as follows:

Mr. Travert, of District No. 39, says his report is incomplete, as he spent almost all of his time on Rifle creek. He complains that Mesa county has refused to pay his bills, so that he and his deputy have been working on half pay all summer.

W. E. Obert, of District No. 41, reports an unprecedented shortage of water. He complains that great injustice is done District No. 41 by the district above, viz., District No. 68, in taking all the water whenever the river is low. The Cimarron ditch is nearly completed, and will bring into the valley fifty cubic feet of water during the dry season. The Bonnie reservoir is about completed, the water from which will be used on Garnet mesa, east of Delta.

S. S. Sease, of District No. 42, reports an unprecedented dry season, with no snow in the mountains and little flood water. He was called out two months earlier than usual. He found the most difficulty in separating the reservoir water, using the natural channel as a conduit from the natural flow, especially where several reservoirs were turning water into the same stream. He recommends the consolidation of reservoir interests under these conditions. He says that the reservoirs are of great value to the districts. "Take the reservoir out of the Plateau valley and the result would be that thousands of acres of land now in a state of fair cultivation, on which are located happy and prosperous homes, would soon become a desert waste. Too much can not be done to encourage the construction and empounding of flood waters." He reports that waters from Leon lake have been diverted to the Delta side of Grand Mesa, to the injury of appropriators on Plateau creek, and that 12,000 acres of crop were injuriously affected by this diversion.

The crop conditions were fairly good, especially fruit and vegetables. The shortage of water has taught the farmers how to use it judiciously and economically.

SUMMARY OF COMMISSIONER'S REPORTS, A. D. 1901.

E. D. SAMAIN, SUPERINTENDENT DIVISION NO. 4.

District No.	Length of Ditches in Miles	Number of Acres Actually Irrigated	Maximum of Water carried during Season of 1901, in Second-Feet	Number of Acres that can be Irrigated	Number of Acres of Alfalfa Irrigated	Number of Acres of Seeded Grasses, other than Alfalfa, Irrigated	Number of Acres of Natural Grasses Irrigated	Number of Acres of Other Crops Irrigated
29	187	8,445	200*	10,107	5,119	198	312	3,128
30	95	6,134	250*	8,229	3,050	495	546	2,043
31*	50	2,000	50	3,000	500	....	500	1,000
32*	175	9,000	150	10,000	5,000	....	2,000	2,000
33	72	3,791	38	6,884	767	500	140	1,900
34	300*	19,548	100*	84,992	5,535	1,248	23	12,742
Totals	879	48,918	786	123,212	19,971	2,441	3,209	19,313

* Estimated; no report.

SUMMARY OF COMMISSIONER'S REPORTS, A. D. 1902.

E. D. SAMAIN, SUPERINTENDENT DIVISION NO. 4.

District No.	Length of Ditches in Miles	Maximum Amount of Water Carried	Number of Acres of Alfalfa	Seeded or Natural Grass	Number of Acres Grain	Number of Acres Fruit	Number of Acres Potatoes	Number of Acres Beets	Number of Acres Miscellaneous Crops	Number of Acres Actually Irrigated	Number of Acres Under Ditch
29	128	....	1,749	3,054	....	10	....	....	1,737	6,550	8,529
30	100	250	3,068	1,344	....	....	....	....	3,051	7,463	10,000*
31	60	50	500	....	....	....	....	....	....	2,200	3,000
32	200	150	5,000	....	....	....	....	....	....	9,000	10,000
33	32	66	1,006	453	....	....	....	....	2,651	4,110	12,716
34	160	184	6,339	953	....	349	....	....	11,057	13,698	25,165
Totals	680	690	17,661	5,804	....	359	....	....	28,496	48,021	59,410

*Estimated.

REPORT OF SUPERINTENDENT OF IRRIGATION, 1901.

Division No. 5.

Hon. A. J. McCune,

State Engineer, Denver, Colorado.

Dear Sir—I have the honor to present to you my report as superintendent of irrigation of Rio Grande Division No. 5 for the irrigation season of 1901, together with the several reports of the water commissioners on duty.

It is said "that by the past we may judge the future." This quotation may apply to some phases of life, but can not be satisfactorily applied to irrigation seasons. For if we judge the coming season by the preceding one, it will be invariably the reverse of our expectations. The irrigation season of 1900 opened with the water sheds of this division heavily covered with snow, which promised an abundance of water throughout the year. But warm southerly winds and excessively hot spring weather soon reduced the snow in the hills so that by June of that year water became short throughout the division and remained so until the close of the season. Nineteen hundred and one opened with less flattering prospects; with a cold, backward spring, which retarded the melting of the snow and gave us throughout the season an abundance of water in nearly all of the districts in the division, which resulted in giving to the division abundant crops and a satisfactory delivery of water.

In seasons such as 1901 it is a pleasure for the irrigation officers to discharge their duties, as we find the water consumers willing to allow the commissioners to distribute the water in accordance with the decrees, and ready to comply with their orders concerning the putting in of headgates, and the repairs of same. This condition of affairs not only enables the commissioners to properly discharge their duties, but decreases the expense on the several counties embraced in the division, through the fact that fewer deputies are required.

I have been enabled this year, through the efforts of the several commissioners, to acquire data of the undecreed

ditches of the division; also the reservoirs which are now in operation. This data I hand you on separate sheets, representing each district reporting. The crops raised under these undecreed ditches are not included in the commissioner's annual report, which is tabulated herewith. I call attention to this, as it will materially increase the crop returns from the division, and will more accurately determine the water duty in each district.

These reports on non-decreed ditches and reservoirs will also give a clearer conception of the difficulties which surround the water commissioners in their several districts in the distribution of water in times of shortage to the decreed rights. As "Preservation is the first law of nature," the undecreed ditch owner, believing in the old adage, and with the addition "that God helps those who help themselves," he therefore gives the commissioner no end of trouble and annoyance in helping himself to the waters of the streams, after the same has been regulated to flow into the decreed ditches. To add to the embarrassing position in which this places the commissioner, the juries before whom these offenders are tried under the irrigation laws of the state, in a great many cases, condone the offense by failing to convict, which act not only lessens the efficiency of the water service, but encourages others in this unlawful practice. I am inclined to believe, however, that it is more leniency on the part of jurors toward the accused than a desire to violate their obligation as such. The laws upon our statute books at the present time are ample to reach all of these offenses, if properly applied, and I am convinced that as the people become better acquainted with the irrigation law and its application that they will guard their rights to the use of water as they would their personal property, and will give evidence to convict and punish the unlawful use of the same.

At various times in the past the question of the right of water commissioners to remove dams and obstructions from the natural streams or water ways has been very seriously doubted by the owners of ditches who have had occasion to build dams in the bed of the streams for the purpose of deflecting the water toward their headgate or ditch. A large number of such dams have caused no small amount of worry in the distribution of water when the streams were low, as they occasion an increased pressure at the headgate, thereby giving an increased amount of water to ditches not entitled to the same, thereby depriving those lower down the stream of their lawful proportion. I have before me a case

in point, wherein Commissioner Obert, of District No. 41, removed a dam from the Uncompahgre river which was constructed by the Sunrise ditch. Suit was brought in the District Court of the seventh judicial district against Commissioner Obert by the owners of the ditch, claiming they were damaged to the extent of $100. The trial of the case was had before Judge Stevens, which resulted in a verdict in favor of the commissioner. The opinion of the court recognizes the authority vested in the water commissioners to use their discretion as to whether a dam is an obstruction, and their right to remove the same. I give herewith Judge Theron Stevens' opinion, which I believe is well worth printing, for the benefit of water users and water commissioners throughout the state:

State of Colorado, County of Montrose, ss.
In District Court.

Robert Sampson, G. G. Russell, P. T. Stevens and L. A. Davidson, plaintiffs,
vs.
William Obert, defendant.

Bill of particulars amending previous notice of nature of action contained in summons.

Plaintiffs in this action are the joint owners and in possession of the Sunrise Ditch, an irrigation ditch diverting water from the Uncompahgre river. That for the purpose of diverting water from said river it is necessary to have a dam in said river at the point of diversion. That on September 24, 1901, plaintiffs were in the lawful possession of a certain dam of the value of twenty dollars, that was constructed and in use by the plaintiffs for the necessary purpose as aforesaid. That in the 24th day of September, 1901, defendant without any authority wilfully and unlawfully demolished, injured and destroyed said dam, all to the plaintiffs damage in the sum of $100.00, said ditch and dam being located in said county and state.

THE RULING.

Ruling of Judge Stevens in Robert Sampson, et al. vs. Obert. The evidence shows that at the time this occurrence took place there was no water in the river that the plaintiffs were entitled to, and that the water commissioner was called upon to have the water turned into a ditch further down the stream, which was an older priority and which was entitled to all the water that was running in the stream at that time.

I am satisfied that under the law the commissioner has a discretion about these matters and that he is presumed to use that discretion with judgment. It is unquestionably his duty to see that the water is properly distributed where it belongs and to those who have a prior right to its use; in doing that, if it becomes necessary to do it, I believe he has the discretion and power to remove any obstructions in the river that would prevent his carrying out what the law requires him to do, and if it was necessary

for him to remove obstructions that had been placed there, even though they may have been of a permanent character, I believe he could do it. Unquestionably also a river differs somewhat from the highways where the road supervisors have full authority. In regard to highways it wouldn't be presumed that any obstructions were necessary to be built in the highway in order that those adjoining should enjoy the full use and benefit of their farms and premises, but this river is a highway for carrying the water and there is no question but those who are entitled to divert water find it necessary quite often to put obstructions in the river and diverting their water in order to get it into the ditch, but that must be done in such a way that no injury will be done to others and the stream obstructed to such an extent that it will be diverted from those who have a prior right to use it. If that is done where persons obstruct a stream in that way I regard it as their duty and for their own protection that they construct in connection with it such outlets or waterways as will permit the diversion or flowing through of all the water without obstruction if it should become necessary to do it. No one has a right to obstruct a stream in such a way that all of the water can not be carried through such obstruction without waste to those below who have a prior right to use it.

Now, in this instance the evidence shows, and I believe fairly shows, that the commissioner attempted to perform his duty in getting the water down below that they had a right to use, and in doing so, as he testifies, he thought by removing the obstruction above that it could be done with less damage to the plaintiffs than to remove the obstruction at the headgate; he attempted to do it that way. Not being able to do it that way he was then forced to go down to the headgate and remove a portion of the obstruction that had been placed there. I can not see, under the circumstances, that the discretion in power which is vested in the commissioner was abused in this case. From the evidence he seems to have acted from his best judgment and used his best judgment. People sometimes make a mistake as to which is the best method of doing these things and the law under such circumstances does not find it necessary to punish a man for a lack of judgment unless by such lack of judgment some one has been injured to some extent, and where discretionary power is conferred upon any one it would be a difficult matter, and rather an unjust matter to impose a penalty where there might have been a lack of judgment in the exercise of that discretion. Now, upon the court is conferred discretionary powers and sometimes those powers are used and exercised with not the very best judgment in the world as we always understand, and yet if a court keeps within the bounds of a legal discretion as they are required to do, they are not held accountable; so it is, it strikes me, with any ministerial, executive or judicial officer where endowed with discretionary power if they do the best they can under the circumstances they ought not to be held accountable. In this instance, however, I don't believe any mistake was made; I am inclined to think that the commissioner did as well as any of us would have done under the circumstances, and possibly better. Now it isn't to be understood that the court holds that these obstructions can not be placed in a river. They can do that, they can fix it so as to turn the water to the very best advantage, but they must leave some spillway so, in case of necessity, they can run every drop of water through there.

So, under the circumstances I feel as if the commissioner had not been guilty of any illegal exercise of power and discretion in the matter, and the judgment will be for the defendant.

I take pleasure in stating that each commissioner in this division has, to the best of his ability, endeavored to discharge his duties in the interest of the water users and the credit of the service. A few, however, have been lax in the matter of reports, which is to be regretted.

The commissioners, in submitting their reports, offer the following comments:

E. E. DOYLE, Water Commissioner of District No. 28:

The following streams have been somewhat short during the past season: Razor, Neddle, Cabin and Hot Springs creeks. Water conditions have been fairly good. Fourteen or fifteen days rainfall. The general condition of the ditches in this district is good; the Arch ditch carrying an excess of two hundred inches. The water users have complied with my instructions and I have met with no difficulty. Affairs were adjusted on Razor creek by an agreement between the water users.

ANDREW KALQUIST, Water Commissioner District No. 37: No report.

GEORGE W. HULL, Water Commissioner District No. 38:

The irrigation season of 1901 being closed, I am proud to report that it has been one of the most prosperous years in my experience as water commissioner (five seasons). The early part of the season looked as though the water supply was going to be very short, but with the exceptions of a very few ditches there has been sufficient water to raise an abundant crop of all kinds. The ranchmen have found out there is a more economical way of using water than they have been in the habit of doing, raising the same amount of crop and in some cases better crops than when they used too much water. I have argued this point for the last five seasons, and I am positive I have got them to fully realize the fact that they can get along with less in some localities and thereby help their neighbors who have later priorities. With the exception of a few minor offences my authority has been well recognized all over the district. If the headgate and rating flume law is enforced by the State Engineer before another season opens we will still have a better and a more satisfactory method of distributing water. In my district there are about three hundred ditches, with only five headgates in good repair, and about thirty-five rating flumes in good condition. If we could influence the owners of all ditches to erect at the head of their ditches a self-registering device it would dispense with all litigation and ill feeling between one another, and by so doing my district would be living in peace and plenty. I would suggest that the State Engineer and Superintendent of Irrigation use their influence so that such devices may be constructed in every ditch where there is trouble over the division of water.

FRANK D. SQUIRES, Water Commissioner District No. 39:

I herewith submit my report, stating that the season throughout my district has been entirely satisfactory, with the exception of a shortage of water on Roan creek. The crops have been a little above the average. There is a feeling of general satisfaction among the water users throughout the district.

M. H. PAYNE, Water Commissioner District No. 40:

The season of 1901, just closed, has been a very profitable one to our fruit growers and farmers, and the water supply has been generally good. Owing to the scattered condition of my district, I mean by this that the numerous streams which flow through my district being so far apart and running in so many different directions, it is impossible to care for and distribute the water without a large number of deputies. And again, the additional calls made upon my time in caring for the numerous reservoirs which are located on the Grand Mesa, through which I have to conduct the natural flow of the streams, upon which they are situated, so as to keep the owners of reservoirs from impounding water in the irrigating season. You will note by reference to my reservoir report that on the head of Dirty George creek I have eleven reservoirs. On the head of Oak creek two reservoirs, on the head of Kaiser creek nine reservoirs, on the head of Ward creek ten reservoirs, Young's creek six reservoirs, on the head of Surface creek, sixteen reservoirs, on the head of Leroux creek ten reservoirs, Hart's basin, one reservoir. These reservoirs are located from one to twenty-five miles apart, and from twenty to thirty miles from the point where the water is used. They are located in the northern part of my district, thirty miles from the southern portion and twenty-five miles from the eastern. The western end of the district is located at Delta, a distance of thirty miles from the reservoirs. I give this outline, as I have been somewhat criticized by the county commissioners of the counties interested for the expense incurred in employing deputy water commissioners.

But it is impossible to get along with a less force. I also submit to you a report of the nondecreed ditches.

W. E. OBERT, Water Commissioner District No. 41:

In my report of this year I wish to say that the supply of water was better than usual and crops have been good. There have been many transfers of water from the early ditches to the late ones; which has been of great benefit to the district. The severe shortage of water last year has caused two new enterprises in the district. One is the construction of a ditch from the Cimarron river to bring the water of that stream into the Uncompahgre valley. This done, it will increase the water supply fifty feet during low water. The other is the building of a reservoir to supply Garnet Mesa. The reservoir is partly constructed and the amount of water stored therein added materially to the water supply of this Mesa this year, and work is now progressing on both of the enterprises.

There are two water districts on the Uncompahgre river, which seems to me is contrary to law, but if not, it is certainly contrary to the best interests of this district, for, in my opinion, the waters of a stream so short should be run by one commissioner. We had very little trouble during the year. I was a party to but one case in court, and that case I had to defend, as suit was brought against me by the Sunrise Ditch company for removing a dam out of the river to get water to an earlier ditch down the river. The case was tried in the District Court and I was upheld by said court. The decision was that the commissioner has the right to remove any obstructions which deprives earlier priorities from getting full benefit of the river channel for running water.

GEORGE H. HALL, Water Commissioner Ditsrict No. 42:

Reports season of 1901 as a very good and prosperous year, with good supply of water. Also submits reservoir report, and nondecreed ditch report. No serious difficulties throughout the season.

E. L. HOUSE, Water Commissioner District No. 45:

In submitting this report for the year 1901 I would say, we have had a good yield of alfalfa, potatoes, grain and fruits of all kinds, except apples, about half a crop, but good quality. Conditions did not differ very materially from the ordinary season. I began regulating water April 26. My services were needed until May 13th. From that time until June 21 there was an excess of water in all the streams. After July 10 there always has been and was a shortage of water this season. As the supply is furnished by living streams, except ditches taking water out of Grand river, there was but little interference with head gates by water users this season. No arrests were made during the year. Nearly all of the decreed ditches have headgates and weirs. There are a good many ditches used that have no decrees, no headgates or weirs. They only expect to use water during the high water or flood season. It would be a good thing to have ditches taken out of the Grand river to irrigate the low bottom lands, as the prior right on the small streams is nearly all at the mouth of the creek emptying into the Grand river. This land could be supplied by Grand river water in District No. 45, and the creek water be given to the ranches on the Mesa. There were only five loans or transfers of water made this season, owing to the fact that we had more rain than last year. In July and August we had from fourteen to fifteen days rain along the Battlement Range. The Battlement Water Storage company has done considerable work on No. 1 dam, and repaired some of the other dams, and will have double the amount of water next year. This year they ran an average of seven and three-tenths feet of water for fourteen days.

O. F. LEROUX, Water Commissioner District No. 52:

Submits his report without comments.

A. R. PLOWMAN, Water Commissioner District No. 53:

The Stewart Irrigation ditch is built half a mile in the Grand river, and during high water that part is out of sight. A gate would be no good.

Egeria creek got down to 2.5 feet in July, the lowest known. Cedar creek goes dry at the lower end every year. July 15 Toponas creek was the lowest for ten years, all but one ditch shut off by the middle of July. Cabin creek was dry by the 14th of June, but the last of July a heavy rain put eight feet of water in the creek for two days, and graduating to one foot for a week. Sunnyside creek was down to 1.7 feet up the creek, but was as much down at Sunnyside ditch, although part of the water in the lower end was from leakage of reservoir of the Grand River Land & Cattle company (now S. H. Bacon's). Horse creek was about as usual. As near as I could find out Little Derby Gulch has waste water from Middle Derby creek water. Raspberry Gulch is fed by a spring during summer, a tributary of King creek. Sutton creek was dry July 20, 1901. McKeen creek, flow about as usual. On this creek apple crop heavy, as also pears, apricots, plums and crab apples. Yarmony creek never has much water after July 1. Rock creek was lower in August than usual. Mason creek supplied by springs. Elk creek failed the last of June, about two weeks earlier than usual. Middle Derby ditch took supply of water from North Derby until that failed. Could not find Ohio creek, none of the old settlers know anything about it. Trail creek about the usual amount of water. Sweetwater creek about the same flow as usual. Spring Creek about as usual. Haak creek a little lower than usual. Little Black Tail creek about as usual. Wright Gulch the same as usual. Skinner creek lower than ordinary. Red Dirt creek, Sheep creek, Antelope creek, North Derby, all had fair runs of water. Mr. Bailey's water wheel in the Grand river, above McCoy, ran from the first of May until August 1. It empties four ten-gallon boxes every one and one-half minutes and irrigated thirty acres of alfalfa. I am sorry to report that I had to have one man arrested (Mr. J. P. Quinlan) and fined for opening a headgate after I had closed the same. The rainy season lasted from eighteen to twenty-one days. For two weeks it rained every day. The first crop of alfalfa was good. The second crop was better than for some years. Timothy and wild grass were short. I think this was on account of the nights being so cold in the early spring. On the whole the crops in this district were good.

O. C. Springer, Water Commissioner District No. 60:

Conditions in District No. 60 were in fairly good shape throughout the season. Some friction was occasioned in the distribution of water by lack of headgates and measuring boxes. The greatest difficulties experienced, however, were on the Naturita Cattle & Land Company ditch. This ditch has great length and the water users on the lower end could not receive sufficient water for the amount of land in cultivation. A great many complaints were made to me from this source, but I was powerless to remedy the conditions. There are two reservoirs in my district, The Naturita Cattle & Land Company's Nos. 1 and 2. Capacity about ten million cubic feet of water.

Wm. Vandegrift, Water Commissioner District No. 61:

I have the honor to submit to you my annual report for 1901. I received my appointment April 13, 1901, and took charge of District No. 61

April 21, 1901. In assuming the duties I was confronted by a great many ideas suggested to me by the water users, as to who was entitled to water and who not. After I had gone over all of the ditches and located all of the headgates, and learned the names of all the owners I found that the decrees differed a great deal from what had been told me. I saw that if I followed the decrees I would have trouble on my hands. There was neither a headgate or measuring flume in the district that could be controlled. I immediately ordered measuring flumes in all the ditches, and in order to get them to comply with the order I was compelled to refuse some of them water. The Farmer's ditch, the P. T. Stevens Land & Cattle Company's ditch, bring their water in from Geyser creek and Deep creek, emptying it into Paradox creek. The water supply in West Paradox creek is a small amount compared to that decree. Seventeen feet is the amount of water decreed and at best there is little more than half this amount in the creek. There are two reservoir sites located in Utah, the waters of which are used in my district. One is located on Geyser creek, and when the dam is completed to its full height will have a capacity of five hundred million cubic feet of water. The dam of this reservoir is not good, and will not store any water the coming season. The other, which is also in Utah, covers about seven acres of land and will be about ten feet deep when completed. In regard to the ditches there is not a good headgate in the entire district. In the month of May there were two good rains, on the 6th and 20th. In June a good rain on the 11th. Light rains occurred on the 9th, 12th, 25th, 26th and 30th of July. Rains from the 7th to the 15th, also on the 21st of August. September it rained on the 2d and 5th, and October it rained on the 5th and 6th. These rains throughout the season helped materially, in consequence of which good crops were raised throughout my district.

H. S. HOLADAY, Water Commissioner District No. 68:

Conditions throughout the season of 1901 in my district were good. Very little complaint was made to me by water users. The result of the season was good crops in grasses and grain, and general contentment among the ranchmen. As districts Nos. 68 and 41 are on the Uncompahgre river, I did, several times during the season, request the ranchmen using water from the Uncompahgre in my district to shut down their headgates and allow their water to go to district No. 41. This they did, materially assisting that district.

Respectfully submitted,

A. F. REEVES,

Superintendent of Irrigation of Grand River Division No. 5.

Montrose, Colorado, January 1, 1902.

REPORT OF SUPERINTENDENT OF IRRIGATION, 1902.

DIVISION NO. 5.

HON. A. J. MCCUNE,

State Engineer, Denver, Colorado.

Dear Sir: I have the honor to hand you my report as superintendent of irrigation of Grand River District No. 5 for the irrigation season of 1902, together with the several reports of the water commissioners on duty in this division.

The season of 1902 will pass into the irrigation history of the state showing the lowest stream gagings in the streams of the Western Slope for the past twenty years. The larger streams, such as the Grand and Gunnison rivers, were reduced to about half of their normal flow, thus indicating the condition of the feeders, which, in the majority of cases, if not totally dry, were nearly so in the early part of July. The valley districts were the worst sufferers, as they are the lowest down on the streams, and did not have the advantage of the more favored mountain districts, which were benefited by light rains. However, the general crops did not fall very far short of the average. During the months of June, July and August the commissioners of the districts experienced great difficulty in delivering the water to the earlier decrees. Demands, threats and proposed action for damages were hurled at them from all sides. But it is to be said to their credit that they have efficiently discharged their duties, and conscientiously delivered the water in accordance with the decrees as they understand the same. And while I have received numerous complaints, and have been called upon to settle differences between the water commissioners and water users, I have found, in a majority of these cases, that the questions arising have either been through a fault in the decree, or a misunderstanding as to its application, or a desire on the part of the one applying for relief to compel the commissioner to give him water to which he was not entitled. I might here say that my experience as superintendent of irrigation causes me to wonder how it is possible for the

water commissioners to give any better satisfaction than they now do. Their duties are only ministerial and defined by statute, which prescribes the limit of their powers. While the decrees, as rendered in the different judicial districts wherein water rights have been adjudicated, would, if literally adhered to, place the commissioner in the position of the court itself, causing him to receive testimony, and, properly speaking, to readjudicate the decrees as handed down to him, it is not my intention to criticise the court which made these decrees. I desire only to point out wherein they are defective in their application; and to this end I now call attention to the several decrees which have been rendered in the districts of Division No. 5.

In District No. 28 the decree recites that five-eighths of one statutory inch is adjudged to be sufficient to irrigate one acres of land, and no greater amount shall be allowed.

In District No. 37, section 8 of the decree recites: "That throughout said District No. 37 one cubic foot of water per second of time is hereby adjudged and decreed to be sufficient in amount to properly and practicably irrigate fifty acres of land, and nothing in this decree shall be taken or held to grant to any tract or parcel of land water to any greater amount than in said ratio and proportion, whether the said land be covered by one or more ditches."

"Ninth. That the priorities hereby established are granted and made absolute. But the user of the respective amounts of water hereby granted and decreed is restricted to the practicable utilization thereof by the parties lawfully entitled thereto. And water is only allowed to flow into said ditches in said ratio and proportion as the land under said ditches, respectively, shall be brought under practicable cultivation. That is to say, tilled, meadow or good pasture land; and, Provided, That the said lands under said ditches, respectively shall be brought under such cultivation, and the said proportionate amount of water used thereon by the parties lawfully entitled thereto, with reasonable diligence."

In District No. 38—"One cubic foot of water per second of time is hereby adjudged and decreed to be sufficient in amount to practicably irrigate fifty acres of land." Paragraphs 8 and 9 of District No. 37 are used in decree of District No. 38.

In District No. 39 the decree recites same paragraphs as 8 and 9 in decrees of Districts Nos. 37 and 38.

In District No. 40, section 6 of the decree recites: "That through water District No. 40 one cubic foot of water per

second of time is hereby adjudged and decreed to be sufficient in amount to properly and practicably irrigate forty acres of land; and nothing in this decree shall be taken or held to grant to any tract or parcel of land water to any greater amount than in said ratio and proportion."

Section 7 practically recites the same provisions as made in paragraph 9 of the foregoing decrees. I here recite one of the decrees of District No. 40, to which I shall hereafter refer, the Sutton ditch. "And it is hereby adjudged and decreed that there be permitted to flow into said ditch from the streams aforesaid for the use and benefit of parties lawfully entitled thereto under and by virtue of the appropriation by original construction prior to No. 5, fifteen cubic feet of water per second of time; Provided, That there shall not be permitted to flow into said ditch from said creek to exceed 5.5 cubic feet of water per second of time until such time as said parties shall increase their cultivated, meadow and pasture lands thereunder over and above the amount of 217 acres; and then the increase in the amount so permitted to flow into said ditches shall only be in the ratio and proportion of one cubic foot per second for each forty acres of such additional lands; and, Provided further, That said increase of said additional land and the users thereon of the said proportionated additional amount of water appropriated therefor be made by said parties with reasonable diligence."

In District No. 41 the decree does not recite the amount of water to be allowed per acre. All decrees are made absolute to the ditches named therein.

In District No. 42 decree is made the same as District No. 41.

In District No. 45 the same provisions are made in its decrees as in Districts Nos. 37, 38 and 39, allowing one cubic foot of water per second of time or sixty cubic feet per minute of time for each fifty acres, and its decrees are all based on the minute flow of water.

A section from the decree of the Dow ditch reads as follows:

"The whole amount of water to which said ditch is at present entitled is 180 cubic feet per minute."

"Provided, That eighty-five cubic feet of water per minute of said last mentioned appropriation shall only be granted and allowed to flow into said ditch from said creek for the use and benefit aforesaid in proportion as said parties shall increase their cultivated, meadow, and feasible irrigable lands

thereunder, over and above the amount of eighty acres in the ratio of sixty cubic feet of water per minute to fifty acres of such additional land."

"And, Provided further, That said increase of said additional lands and the user of the said proportionate additional amount of water appropriated therefor, thereon, be made by said parties with reasonable diligence."

In District No. 52 the same provisions in decrees are made as in Districts Nos. 37, 38 and 39.

In District No. 53 the same provisions are made as in District No. 52.

In District No. 60 no provision is made for the amount of water per acre, and decrees are made absolute to the several ditches in statutory inches.

In District No. 61, section 6 of the decree reads as follows:

"That throughout Water District No. 61 one cubic foot of water per second of time is hereby adjudged and decreed to be sufficient in amount to properly and practicably irrigate in that part of Water District No. 61, known as Paradox valley, sixty acres of land. In that part of Water District No. 61 known as Dolores river valley, fifty acres of land. In that part of Water District No. 61 known as Lost Canon creek, fifty acres of land. In that part of Water District No. 61 known as Montezuma valley, sixty-five acres of land. In that part of Water District No. 61 known as Turkey creek, eighty acres of land. And nothing in this decree shall be taken or held to grant to any tract or parcel of land water to any greater amount than in said ratio and proportion.

In District No. 68, section 8 of the decree reads as follows:

"That throughout said Water District No. 68, one cubic foot of water per second of time is hereby adjudged and decreed to be sufficient in amount to properly and practicably irrigate forty acres of adobe land, and proportionately more or less as the land is more or less porous than adobe, and nothing in this decree shall be taken or held to grant any tract or parcel of land, water to any greater amount than in said ratio and proportion."

It is evident from the language of the decrees that to carry out their provisions, water commissioners would be required to know the exact amount of land irrigated by the several interested parties under each ditch, and to see to it that the ratio per acre of water decreed thereto was not ex-

ceeded. Again, they would be required to know the exact amount of land in cultivation under each ditch at the time the decree was granted, so as to enable them to allow a proper proportion of water for the increased acreage put under cultivation. Thus the decrees impose services on the water commissioners, which, in my opinion, they are not called upon to perform, under the language of the statute defining their duties.

In some districts of this division commissioners have undertaken to follow the decree, allowing water for the additional acreage put in cultivation from time to time. This practice has brought on serious complications, which necessitated a ruling on the question by the Superintendent of Irrigation. I, therefore, instructed each commissioner of the division not to recognize any demand for water for increased acreage, or to interfere with or cut down the amount of water decreed to any one ditch when complaint was made to them that the decreed amount of water for said ditch was in excess of the land in cultivation under such ditch, and thereby exceeding the amount of water allowed per acre. These instructions were issued by me after arriving at the following conclusions:

First—That the statute does not invest the commissioners with judicial powers. Hence they would have no right to increase or diminish the amount of water to be delivered by them to any ditch set forth in the decrees.

Second—That their duties ended at the headgate of the ditch, and it was not incumbent on them to see to the division of the water among the individual users of same from said ditch, but merely to deliver the water to said ditch in the amount named in the decree, without reference to any subsequent provisions in said decree.

Third—Each decree must be looked upon, according to our Supreme Court decisions, as a vested right. Therefore, if we were to allow the commissioners to deliver water under any decree for increased acreage it would, in many cases, confiscate the decreed and vested rights of those drawing water from the same stream. For, in a majority of cases, the original decrees have entirely allotted more than the flow of the streams.

Fourth—It is, in my opinion, incumbent on those desiring an increased amount of water to irrigate lands brought under cultivation subsequent to the granting of their original decrees, must again apply to the court for relief, passing

through the same process of giving proof as to the additional number of acres in cultivation, as they did in obtaining their original decrees, and let the court decide what, if any, additional amount of water they are entitled to, and in what order their additional decrees shall be numbered, with respect to the order of the original decrees as granted. This, in brief, is my reason for issuing instructions to the commissioners as before mentioned.

All of the commissioners of this division have made their annual reports with the exception of District No. 37, Andrew Kalquist; commissioner of District No. 60, O. S. Springer (who is excusable from the fact that he has been seriously ill for the past three months), and commissioner of District No. 61, William Vandergrift.

The reports of the several commissioners having been made in commissioners' field books, prepared in your office, and said books having been duly forwarded to you, I would request that their field notes as therein contained be added to my report of this division.

Thanking you for the numerous courtesies extended to me in the discharge of my duties as one of your subordinates, and with the knowledge that the relations between us have always been pleasant, I beg to remain,

Yours respectfully,

A. F. Reeves,

Superintendent of Irrigation, Division No. 5.

SUMMARY OF COMMISSIONER'S REPORTS, A. D. 1902.

A. F. REEVES, SUPERINTENDENT DIVISION NO. 5.

District No.	Length of Ditches in Miles	Maximum Amount of Water Carried	Number of Acres of Alfalfa	Number of Acres of Natural Grass	Number of Acres of Grain	Number of Acres of Fruit	Number of Acres of Potatoes	Number of Acres of Beets	Number of Acres of Miscellaneous Crops	Number of Acres Actually Irrigated	Number of Acres Under Ditch
28	42	....	....	6,490	....	....	....	....	....	6,490	10,000
36*	....	....	....	....	....	....	....	....	....	....	....
37	....	....	....	....	....	....	....	....	....	....	....
38a	215	339	5,842	3,327	1,836	181	1,432	13	65	12,696	17,000
39	215	191	5,849	329	899	1,464	466	47	440	9,571	14,209
40a	335	300	15,000	1,500	5,000	5,000	....	....	3,000	100,000	100,000
41	245	200	9,291	1,000	6,345	2,100	805	....	21	18,542	61,170
42a	125	100	7,852	150	....	800	....	....	2,000	....	71,000
45	100	219	6,474	945	830	603	315	45	226	9,240	19,013
50*	....	....	....	....	....	....	....	....	....	....	....
51*	....	....	....	....	....	....	....	....	....	....	....
52	18	34	392	433	41	2	6	....	11	886	1,604
53	101	205	1,778	3,288	93	7	4	....	1,392	7,562	10,183
59*	....	....	....	....	....	....	....	....	....	....	....
60	....	....	....	....	....	....	....	....	....	....	....
61a	22	....	470	200	....	....	....	....	100	....	1,000

62*	....	....	....	....	....	....	....	....	....	....	....
63*	....	....	....	....	....	....	....	....	....	....	....
68	83	254	1,939	2.672	877	63	167	....	40	5,758	8,934
69	....	....	....	....	....	....	....	....	....	....	....
Totals	1.501	2,043	64,887	20,334	15,921	10,220	3,195	105	7,295	271,245	314,113

* No commissioner appointed.
a No report. Amounts estimated from previous reports.

REPORT OF SUPERINTENDENT OF IRRIGATION, DIVISION NO. 6.

Steamboat Springs, Colorado, November 17, 1902.

Hon. Addison J. McCune,
State Engineer, Denver, Colorado.

My Dear Sir: I duly received Water Commissioner J. D. Moog's crop report to-day, and forward the same by to-day's mail. I can not use your field books in Routt county, for, although there are six water districts in the county and water district No. 58 has over 140 ditches, still the county commissioners, under the advice of County Attorney J. R. Harding, neglect and refuse to accommodate the appointment of water commissioners for Routt county. Hence I was compelled to use the old blanks and forwarded them last week. There has been no priorities correctly numbered by the District Court for ten years in Routt county or since Judge Joshua Walbridge as referee closed the general adjudication of water districts in 1893, and hence it is impossible for the superintendent of irrigation to close headgates since he has no priorities to guide him. Very truly yours,

Peter F. Reinhardt,
Superintendent of Irrigation Division No. 6.

J. D. Moog, who reports from division No. 6, says of District No. 43 that 1902 was the dryest known, there having been scarcely any snow for three years past; that the springs dried up early and the cattle have done considerable damage to the vegetation and springs, the range being somewhat overstocked for so dry a season. The White river had sufficient water to supply all ditches, with a considerable surplus. Further development will necessitate the expenditure of considerable money, as future ditches will be expensive to construct. A ditch from the White river under construction will irrigate lands on Flag creek and leave Flag creek water for other ditches. On Piceance creek numerous small reservoirs are being built. Five arrests were made during the season. In

one case the jury declared "that the law which makes the fact of a party using the water prima facie evidence of his having taken the water was no good;" in another case the justice said that the accused was not guilty because he only had the water one hour when I caught him, and in another case where a man did not run the water through his ditch, but simply put dams in the creek about fifty yards apart all through his land and so diverted the water that belonged to others, the said justice decided that the man was not guilty because I did not charge him with raising his headgate. Where juries and justices make such decrees as these it makes it very hard to enforce the law.

SUMMARY OF COMMISSIONER'S REPORTS, A. D. 1901.

PETER F. REINHARDT, SUPERINTENDENT DIVISION NO. 6.

District No.	Length of Ditches in Miles	Number of Acres Actually Irrigated	Number of Days Water was Carried	Average Amount of Water carried during Season of 1901, in Second-Feet	Number of Acres that can be Irrigated	Number of Acres of Alfalfa Irrigated	Number of Acres of Seeded Grasses, other than Alfalfa, Irrigated	Number of Acres of Natural Grasses Irrigated	Number of Acres of Fruits Irrigated	Number of Acres of Other Crops Irrigated	Number of Acres Irrigated from Seepage
43	150	12,838	180	281	14,065	3,503	1,656	5,343	8	2,253	75
44	93	11,786	120	229	13,610	5,321	4,255	1,780	....	430	....
57	104	18,546	180	355	21,557	5,910	7,356	2,145	....	3,135	....
58	168	20.359	90	452	25,668	35	15,661	3,518	....	1,145	....
Totals	515	63,529	180	1,317	84,900	14,769	28,928	12,786	8	6,963	75

NOTE. Districts 54 and 55 did not report.

SUMMARY OF COMMISSIONER'S REPORTS, A. D. 1902.

PETER F. REINHARDT, SUPERINTENDENT DIVISION NO. 6.

District No.	Length of Ditches in Miles	Maximum Amount of Water Carried	Number of Acres of Alfalfa	Number of Acres of Natural Grass	Number of Acres in Grain	Number of Acres of Fruit	Number of Acres of Potatoes	Number of Acres in Beets	Number of Acres of Miscellaneous Crops	Number of Acres Actually Irrigated	Number of Acres Under Ditch
43	96	303	2,808	4,413	1,629	8	3	....	1.140	10,001	10,217
44	43	157	5,125	3,400	....	....	....	....	505	9,030	9,440
54	22	52	230	1,980	....	....	....	....	595	2,805	3,115
55	....	....	....	....	....	....	....	....	....	....	....
56	9	17	....	710	....	....	....	....	105	815	1,005
57	109	376	7,410	12,065	....	....	....	....	1,705	21,180	22,558
58	156	521	150	22,277	....	....	....	....	2,430	24,857	31,325
Totals	435	1,426	15,713	44,845	1,629	8	3	....	6,480	68,688	77,660

CHAPTER V.

SUMMARY OF DITCH AND RESERVOIR FILINGS.

FROM DECEMBER 1, 1900, TO DECEMBER 1, 1902.

DIVISION NO. 1

DISTRICT NO.	Number of Ditches	Capacity Claimed in Second-Feet	Number of Reservoirs	Capacity in Cubic Feet
1....................	22	5,536.8	12	4,221,540,054
2....................	20	654.0	13	152,378,610
3....................	21	782.5	32	5,480,426,892
4....................	9	96.0	15	3,093,864,499
5....................	2	19.2	7	757,566,934
6....................	6	274.98	2	24,641,800
7....................	3	58.0	None	....
8....................	8	71.22	2	1,700,550
9....................	1	4.	2	16,362,542
23....................	20	1,021.85	None	....
46....................	6	236.0	1	14,165,712
47....................	13	148.0	None	....
48....................	15	278.02	9	335,140,425
64....................	20	4,054.52	1	5,353,336
65....................	None	....	None	....
Totals...........	156	13,735.85	95	14,103,141,354

SUMMARY OF DITCH AND RESERVOIR FILINGS.

FROM DECEMBER 1, 1900, TO DECEMBER 1, 1902.

DIVISION NO. II.

DISTRICT NO.	Number of Ditches	Capacity Claimed in Second-Feet	Number of Reservoirs	Capacity in Cubic Feet
10	7	401.36	8	16,653,158
11	1	5.	2	544,500,000
12	5	55.93	4	348,844,160
13	1	2.	None	....
14	8	552.75	5	156,675,335
15	1	3.	2	1,220,374,960
16	7	75.	None	....
17	16	453.14	8	771,680,544
18	1	130.	1	2,003,760,000
19	24	435.5	1	4,558,554,000
49	2	124.	None	....
66	None	....	None	....
67	13	193.13	1	1,155,000
Totals	88	2,400.81	32	9,621,897,157

SUMMARY OF DITCH AND RESERVOIR FILINGS.

FROM DECEMBER 1, 1900, TO DECEMBER 1, 1902.

DIVISION NO. III.

DISTRICT NO.	Number of Ditches	Capacity Claimed in Second-Feet	Number of Reservoirs	Capacity in Cubic Feet
20	12	514.34	6	761,703,870
21	1	51.	None	....
22	5	1,124.26	2	764,144,280
24	None	....	None	....
25	3	10.32	None	....
26	None	....	None	....
27	None	....	None	....
35	None	....	None	....
Totals	21	1,699.92	8	1,525,848,150

SUMMARY OF DITCH AND RESERVOIR FILINGS.

FROM DECEMBER 1, 1900, TO DECEMBER 1, 1902.

DIVISION NO. IV.

DISTRICT NO.	Number of Ditches	Capacity Claimed in Second-Feet	Number of Reservoirs	Capacity in Cubic Feet
29....................	10	92.5	None	....
30....................	14	583.98	1	17,424,000
31....................	21	154.5	None	....
32....................	None	....	None	....
33....................	3	54.	1	45,594,440
34....................	3	75.	None	....
Totals...........	51	939.98	2	63,018,440

SUMMARY OF DITCH AND RESERVOIR FILINGS.

FROM DECEMBER 1, 1900, TO DECEMBER 1, 1902.

DIVISION NO.V.

DISTRICT NO.	Number of Ditches	Capacity Claimed in Second-Feet	Number of Reservoirs	Capacity in Cubic Feet
28....................	8	129.01	None	....
36....................	17	645.20	None	....
37....................	16	111.	2	392,431,200
38....................	15	278.48	4	134,532,620
39....................	11	49.95	...	3,267,000
40....................	30	357.10	32	373,837,267
41....................	18	1,563.85	2	156,610,030
42....................	12	349.73	6	232,462,200
45....................	4	613.	None	....
50....................	1	9.86	None	....
51....................	29	5,766.26	None	....
52....................	3	21.5	None	....
53....................	8	836.0	...	1,861,490
59....................	28	662.41	4	35,054,055
60....................	21	413.3	1	36,600,000
61....................	1	15.	None	....
62...........	11	184.25	None	....
63....................	1	2.	None	....
68....................	1	30.	None	....
69....................	2	6.	None	....
Totals...........	237	12,203.90	51	1,366,655,862

SUMMARY OF DITCH AND RESERVOIR FILINGS.

FROM DECEMBER 1, 1900, TO DECEMBER 1, 1902.

DIVISION NO. VI.

DISTRICT NO.	Number of Ditches	Capacity Claimed in Second-Feet	Number of Reservoirs	Capacity in Cubic Feet
43	27	281.11	15	162,980,006
44	21	669.66	1	3,510,065
54	8	59.22	1	5,432,500
55	None	....	...	None
56	None	....	1	348,480,000
57	5	777.	None	....
58	15	103.	2	315,289,080
Totals	76	1,889.99	20	835,691,645

TOTALS.

DIVISION NO.	Number of Ditches	Capacity Claimed in Second-Feet	Number of Reservoirs	Capacity in Cubic Feet
1	156	13,735.85	95	14,103,141,354
2	88	2,400.81	32	9,621,897,157
3	21	1,699.92	8	1,525,848,150
4	51	939.98	2	63,018,440
5	237	12,203.90	51	1,366,655,862
6	76	1,889.99	20	835,691,645
Total for state	629	31,670.45	208	27,516,252,608

TABLE

GIVING DITCH DECREES IN IRRIGATION DISTRICT NO. 47, AS PREPARED BY THE SUPERINTENDENT OF IRRIGATION OF WATER DIVISION NO. 1, FROM THE CERTIFIED COPY OF DECREES GOVERNING APPROPRIATIONS IN THE DISTRICT. FURNISHED HIM BY THE CLERK OF THE DISTRICT COURT ISSUING SUCH DECREES. READJUDICATION MARCH 4, 1902. CHRISTIAN A. BENNETT, JUDGE.

NAME OF DITCH	Source of Supply	Date	Amount in Second-Feet Decreed to Each Priority.	Total Amount in Second-Feet Decreed to each Ditch or Canal	Total Amount in Second-Feet Previously Decreed in District	Order of Priority in District
Owl ditch	Owl creek	May 15, 1880	2	....	....	1
Capron ditch	Pinkham creek	June 21, 1880	2	....	2	2
Kerr ditch	Little Willow creek	May 14, 1882	1	....	4	3
Oliver ditch	Little Willow creek	May 15, 1882	1	....	5	4
J. W. Sutton ditch	E. Fork Willow creek	May 20, 1882	4	....	6	5
Hanover ditch	Big Willow creek	June 1, 1882	1	....	10	6
Coe ditch No. 2	Government creek	June 21, 1882	1	....	11	7
Coe ditch No. 1	Government creek	June 21, 1882	1.5	....	12	8
Cochrane ditch	Big Willow creek	June 21, 1882	1	....	13.5	9
Cameron Pass ditch	Tributaries Michigan river	July 30, 1882	10	....	14.5	10
Home ditch No. 1	Illinois river	May 6, 1883	4	....	24.5	11
North Park ditch No. 2	Spring creek	May 15, 1883	3	....	28.5	12
Newport ditch	Pinkham creek	May 31, 1883	2	....	31.5	13

Endomile ditch	Illinois river	June 1, 1883	2	....	33.5	14
Government ditch No. 1	Government creek	June 30, 1883	4	....	35.5	15
Flying Dutchman ditch	Illinois river	June 1, 1884	2.5	....	39.5	16
Weed ditch	Illinois river	June 1, 1884	2.5	....	42	17
Coe ditch No. 1	Government creek	June 21, 1884	1.5	3	44.5	18
Salem ditch	Big Willow creek	June 30, 1884	1.5	....	46	19
Coe ditch No. 2	Government creek	July 1, 1884	1	2	47.5	20
Moore ditch No. 1	Government creek	Aug. 1, 1884	1	....	48.5	21
Sherman ditch	Sherman creek	Oct. 15, 1884	4	....	49.5	22
Chace ditch	Sherman creek	Oct. 31, 1884	10	....	53.5	23
Hi Ho ditch	Michigan creek	April 1, 1885	6	....	63.5	24
Buckeye ditch	Michigan creek	April 15, 1885	2	....	69.5	25
Senaca ditch	Michigan creek	April 15, 1885	1	....	71.5	26
Matthews ditch	Michigan creek	May 1, 1885	8	....	72.5	27
Donelson ditch	Little Willow creek	May 4, 1885	6	....	80.5	28
Monroe ditch	Illinois river	May 5, 1885	3.5	....	86.5	29
Livingstone ditch	Government creek	May 10, 1885	1	....	90	30
Walden ditch	S. F. Michigan river	May 12, 1885	8	....	91	31
William Kerr ditch	Elk creek	May 15, 1885	3	....	99	32
Lower Walden ditch	Michigan river	May 15, 1885	6.5	....	102	33
Jakey ditch	Michigan river	May 15, 1885	3	....	108.5	34
Shearer ditch	Willow creek	May 16, 1885	3	....	111.5	35
Yocum ditch No. 1	Sherman creek	May 31, 1885	1.5	....	113	36
Ruction ditch	Michigan river	May 31, 1885	3	....	116	37
Big Willow ditch	Big Willow creek	June 1, 1885	5	....	121	38

TABLE

GIVING DITCH DECREES IN IRRIGATION DISTRICT NO. 47, AS PREPARED BY THE SUPERINTENDENT OF IRRIGATION OF WATER DIVISION NO. 1, FROM THE CERTIFIED COPY OF DECREES GOVERNING APPROPRIATIONS IN THE DISTRICT, FURNISHED HIM BY THE CLERK OF THE DISTRICT COURT ISSUING SUCH DECREES. READJUDICATION MARCH 4, 1902. CHRISTIAN A. BENNETT, JUDGE.—Continued.

NAME OF DITCH	Source of Supply	Date	Amount in Second-Feet Decreed to each Priority	Total Amount in Second-Feet Decreed to each Ditch or Canal	Total Amount in Second-Feet Previously Decreed in District	Order of Priority in District
Yocum ditch No. 2	Sherman creek	June 1, 1885	2	....	123	39
North Park ditch No. 3	Mendenhall creek	June 5, 1885	3	....	126	40
Home ditch No. 2	Illinois river	June 10, 1885	4	....	130	41
Peabody ditch	Willow creek	June 15, 1885	7.5	....	134	42
Lowland ditch	Owl creek	June 15, 1885	2	....	141.5	43
Hamilton ditch	Spring creek	June 30, 1885	2	....	143.5	44
Coe ditch No. 2	Government creek	July 1, 1885	2	4	145.5	45
Snide ditch	Little Willow creek	July 1, 1885	1	....	147.5	46
Moore ditch No. 1	Government creek	Oct. 1, 1885	2	3	148.5	47
Mansfield ditch No. 1	Michigan river	April 1, 1886	1	....	150.5	48
Seneca ditch	Michigan river	April 12, 1886	2	3	151.5	49
Shearer ditch No. 2	Willow creek	April 14, 1886	1	....	153.5	50
Soldiers' Home ditch	Owl creek	April 30, 1886	2	....	154.5	51

Richmond ditch	Michigan river	May 5, 1886	2	....	156.5	52
Bona Fide ditch	Canadian river	May 10, 1886	2	....	158.5	53
James W. Sutton ditch No. 2	East Fork Willow creek	May 15, 1886	3	....	160.5	54
Michigan High Line ditch	Michigan river	May 31, 1886	1.5	....	163.5	55
Edith ditch	Michigan river	May 31, 1886	2	....	165	56
Pioneer ditch	Illinois river	May 31, 1886	10	....	167	57
Saint Francis ditch No. 1	Yocum creek	May 31, 1886	2	....	177	58
Sudduth ditch No. 1	Cabin creek	June 1, 1886	4	....	179	59
Saint Francis ditch No. 2	Yocum creek	June 5, 1886	1	....	183	60
Lowland ditch	Owl creek	June 21, 1886	2	4	184	61
Government ditch No. 2	Government creek	June 21, 1886	8	....	186	62
Fernando ditch	Cabin creek	June 30, 1886	3	....	194	63
J. W. Sutton ditch	East Fork Willow creek	June 30, 1886	4	8	197	64
Victor ditch	East Fork Big Willow creek	June 30, 1886	1	....	201	65
Stevenson ditch No. 3	Willow creek	June 30, 1886	1	....	202	66
Matthews ditch	Michigan river	Mar. 31, 1887	6	14	208	67
Midland ditch	Illinois river	April 1, 1887	14	....	209	68
Cumberland ditch	Michigan river	April 1, 1887	3	....	223	69
North Park ditch No. 5	Michigan river	April 5, 1887	4	....	226	70
Moore ditch No. 2	Michigan river	April 15, 1887	8	....	230	71
Landhurst ditch	Spring creek	April 25, 1887	1.5	....	238	72
Allen ditch	Allen or Willow Creek	April 25, 1887	2	....	239.5	73
Buckeye ditch	Michigan river	April 30, 1887	6	8	241.5	74
Coon Creek ditch	Coon creek	April 30, 1887	5	....	247.5	75
Stella ditch	Illinois river	April 30, 1887	4	....	252.5	76

TABLE

GIVING DITCH DECREES IN IRRIGATION DISTRICT NO. 47, AS PREPARED BY THE SUPERINTENDENT OF IRRIGATION OF WATER DIVISION NO. 1, FROM THE CERTIFIED COPY OF DECREES GOVERNING APPROPRIATIONS IN THE DISTRICT, FURNISHED HIM BY THE CLERK OF THE DISTRICT COURT ISSUING SUCH DECREES. READJUDICATION MARCH 4, 1902. CHRISTIAN A. BENNETT, JUDGE.—Continued.

NAME OF DITCH	Source of Supply	Date	Amount in Second-Feet Decreed to each Priority	Total Amount in Second-Feet Decreed to each Ditch or Canal	Total Amount in Second-Feet Previously Decreed in District	Order of Priority in District
Kerr ditch	Willow creek	April 30, 1887	1	2	256.5	77
Leonard ditch	Illinois river	April 30, 1887	5		257.5	78
Enlargement of Seneca ditch	Michigan river	May 1, 1887	4		262.5	79
North Park ditch No. 6	Illinois river	May 1, 1887	9		264.5	80
Dryer ditch	Illinois river	May 1, 1887	5.2		273.5	81
Stella ditch	Illinois river	May 1, 1887	5.6	9.6	278.7	82
Phelan ditch	McKenzie creek	May 1, 1887	1.75		284.3	83
Seneca ditch	Michigan river	May 1, 1887	20	23	286.05	84
Dora ditch	East Willow creek	May 5, 1887	1		306.05	85
Everhard and Baldwin ditch	Illinois river	May 8, 1887	10		307.05	86
Hanover ditch	Big Willow creek	May 15, 1887	3.5	4.5	317.05	87
Stevenson ditch No. 2	Willow creek	May 15, 1887	5		320.55	88
Carpenter ditch	Canadian river	May 15, 1887	.6		325.55	89

Ish and Everhard ditch	Illinois river	May 24, 1887	6	....	326.15	90
Rarus ditch	Spring creek	May 31, 1887	2	....	332.15	91
Michigan High Line ditch	Michigan river	May 31, 1887	1	2.5	334.15	92
Richmond ditch	Michigan river	May 31, 1887	2	4	335.15	93
North Park ditch No. 4	Michigan river	June 4, 1887	8	....	337.15	94
Harry Hadden ditch	Government creek	June 10, 1887	1	....	345.15	95
Wyckoff ditch	Little Willow creek	June 14, 1887	1.5	....	346.15	96
Salem ditch	Big Willow creek	June 15, 1887	2.5	4	346.15	97
Walker ditch	Pinkham creek	June 21, 1887	2	4	348.65	98
Capron ditch	Pinkham creek	June 21, 1887	2	....	350.65	99
Hubbard ditch No. 1	Illinois river	June 21, 1887	1	....	352.65	100
Bona Fide ditch	Canadian river	June 29, 1887	2	4	353.65	101
Bostwick ditch	Michigan river	June 30, 1887	2.5	....	355.65	102
Fernando ditch	Cabin creek	July 1, 1887	2	5	358.15	103
Accommodation ditch	Jack creek	July 15, 1887	12.5	....	360.65	104
Moore ditch	Pinkham creek	Sept. 1, 1887	3	....	363.65	105
Sanborn ditch	Canadian river	Sept. 26, 1887	10	....	366.65	106
Moore ditch No. 1	Government creek	Oct. 1, 1887	2	5	376.65	107
Island ditch	Illinois river	Oct. 1, 1887	1	....	378.65	108
Shearer ditch	Willow creek	Nov. 1, 1887	1	4	379.65	109
Hubbard ditch No. 1	Illinois river	Dec. 1, 1887	3	....	380.65	110
Champion ditch	Michigan river	April 15, 1888	1.5	....	383.65	111
Mansfield ditch No. 2	Michigan river	April 15, 1888	1.5	....	385.15	112
Ish ditch	West Fork Big Willow creek	April 15, 1888	2	....	386.65	113
Ottawa ditch	Illinois river	April 20, 1888	1.5	....	388.65	114

TABLE

GIVING DITCH DECREES IN IRRIGATION DISTRICT NO. 47, AS PREPARED BY THE SUPERINTENDENT OF IRRIGATION OF WATER DIVISION NO. 1, FROM THE CERTIFIED COPY OF DECREES GOVERNING APPROPRIATIONS IN THE DISTRICT, FURNISHED HIM BY THE CLERK OF THE DISTRICT COURT ISSUING SUCH DECREES. READJUDICATION MARCH 4, 1902. CHRISTIAN A. BENNETT, JUDGE.—Continued.

NAME OF DITCH	Source of Supply	Date	Amount in Second-Feet Decreed to each Priority	Total Amount in Second-Feet Decreed to each Ditch or Canal	Total Amount in Second-Feet Previously Decreed in District	Order of Priority in District
Cleveland ditch	Michigan river	April 30, 1888	5.5	....	390.15	115
Oxford ditch	Government creek	April 30, 1888	1.5	....	395.65	116
Squibob ditch	Michigan river	April 30, 1888	6	....	397.15	117
Lizzie ditch	Elk creek	May 15, 1888	1	....	403.15	118
Park ditch	Illinois river	May 15, 1888	3.5	....	404.15	119
School Section ditch	East Fork Willow creek	May 15, 1888	6	....	407.65	120
Ivey ditch	Jack creek	May 15, 1888	5	....	413.65	121
Ward ditch No. 1	Illinois river	May 15, 1888	3	....	418.65	122
Cowdrey ditch	Michigan creek	May 15, 1888	19	....	421.65	123
Terrell ditch	Michigan river	May 16, 1888	3	....	440.65	124
Poverty Flat ditch	Michigan river	May 20, 1888	3	....	443.65	125
Slew ditch	Illinois river	May 24, 1888	4	....	446.65	126
Col. Davis ditch	Michigan river	May 25, 1888	4	....	450.65	127

Howard ditch	Willow creek	May 25, 1888	8	....	454.65	128
Spaulding ditch	Pinkham creek	May 27, 1888	1	....	462.65	129
Overland ditch	Michigan river	May 31, 1888	6	....	463.65	130
Mansfield ditch No. 1	Michigan river	May 31, 1888	2	3	469.65	131
Watson ditch	Pinkham creek	May 1888	2.5	....	471.65	132
Maggie ditch	Allen creek	June 1, 1888	3.5	....	474.15	133
Enlargement of the Seneca ditch	Michigan river	June 1, 1888	1	....	477.65	134
Flying Dutchman ditch	Illinois river	June 1, 1888	6.5	9	478.65	135
Troy ditch	Owl Creek	June 1, 1888	5	....	485.15	136
Sand Creek ditch	Canadian river	June 1, 1888	18.1	....	490.15	137
Rattler ditch	Willow creek	June 2, 1888	2	....	508.25	138
No. 1 ditch	Jack creek	June 2, 1888	3	....	510.25	139
Martin ditch No. 1	Michigan river	June 14, 1888	3	....	513.25	140
Wyckoff ditch	Little Willow creek	June 14, 1888	1	2.5	516.25	141
Jakey ditch	Michigan river	June 15, 1888	2	5	517.25	142
Salem ditch	Big Willow creek	June 15, 1888	2	6	519.25	143
Jay ditch	Jack creek	June 20, 1888	4.8	....	521.25	144
Soldiers' Home ditch	Owl Creek	June 21, 1888	2	4	526.05	145
Moore ditch No. 3	Michigan river	June 21, 1888	6	....	528.05	146
Dora ditch	East Willow creek	June 21, 1888	2	3	534.05	147
Hanover ditch	Big Willow creek	June 21, 1888	1.5	6	536.05	148
Midland ditch	Illinois river	June 22, 1888	6	20	537.55	149
Crystal Springs ditch	Crystal Spring creek	June 22, 1888	1	....	543.55	150
Fernando ditch	Cabin creek	July 1, 1888	1	6	544.55	151
Bern ditch	Big Government creek	July 15, 1888	9.6	....	545.55	152

TABLE

GIVING DITCH DECREES IN IRRIGATION DISTRICT NO. 47, AS PREPARED BY THE SUPERINTENDENT OF IRRIGATION OF WATER DIVISION NO. 1, FROM THE CERTIFIED COPY OF DECREES GOVERNING APPROPRIATIONS IN THE DISTRICT, FURNISHED HIM BY THE CLERK OF THE DISTRICT COURT ISSUING SUCH DECREES. READJUDICATION MARCH 4, 1902. CHRISTIAN A. BENNETT, JUDGE.—Continued.

NAME OF DITCH	Source of Supply	Date	Amount in Second-Feet Decreed to each Priority	Total Amount in Second-Feet Decreed to each Ditch or Canal	Total Amount in Second-Feet Previously Decreed in District	Order of Priority in District
North Park ditch No. 7	Michigan river	Aug. 3, 1888	4	....	555.15	153
William Kerr ditch	Elk creek	Aug. 15, 1888	5	8	559.15	154
Saint Francis ditch No. 7	Christy creek	Sept. 4, 1888	6	....	564.15	155
Saint Francis ditch No. 1	Yocum creek	Sept. 5, 1888	2	4	570.15	156
Boomerang ditch	Michigan river	Sept. 14, 1888	1	....	572.15	157
Col. Davis ditch	Michigan river	Sept. 20, 1888	4	8	573.15	158
Saint Francis ditch No. 2	Yocum creek	Sept 20, 1888	2	3	577.15	159
Lost Treasure ditch	Michigan river	Sept. 25, 1888	55	....	579.15	160
Hill and Crouter ditch	Illinois river	Sept. 25, 1888	6	....	632.15	161
Matthews Eastern ditch	Michigan river	Sept. 30, 1888	4	....	638.15	162
Kiwa ditch	Michigan river	Oct. 17, 1888	1	....	642.15	163
Poverty Flat ditch	Michigan river	Nov. 1, 1888	7	....	643.15	164
Poquette ditch	Michigan river	Nov. 15, 1888	.5	....	650.15	165

Cumberland ditch	Michigan river	Mar. 19, 1889	6	9	650.65	166
Hubbard No. 2 ditch	Illinois river	April 2, 1889	3	....	656.65	167
Alma ditch	Michigan river	April 4, 1889	4	....	659.65	168
Olive ditch	Illinois river	April 15, 1889	2	....	663.65	169
Oklahoma ditch	Illinois river	April 15, 1889	41	....	665.65	170
Bona Fide ditch No. 2	Canadian river	April 20, 1889	3	....	706.65	171
Park View ditch	Illinois river	April 20, 1889	1.5	....	709.65	172
Matthews Eastern ditch	Michigan river	April 30, 1889	2	6	711.15	173
Rattler ditch	Willow creek	April 30, 1889	.5	2.5	713.15	174
Lowland ditch, enlargement and extension	Owl creek	April 30, 1889	1	....	713.65	175
Ruction ditch	Michigan river	May 1, 1889	3	....	714.65	176
Gardner ditch	Michigan creek	May 1, 1889	4	....	717.65	177
Kenney ditch	McKenzie creek	May 1, 1889	8	....	721.65	178
Toledo ditch	Allen creek	May 5, 1889	3	....	724.65	179
Upland ditch	Illinois river	May 5, 1889	2	....	727.65	180
No. 1 ditch	Jack creek	May 6, 1889	1	4	729.65	181
Big Willow enlargement	Big Willow creek	May 15, 1889	1	....	730.65	182
Stevenson ditch No. 4	Willow creek	May 15, 1889	6	....	731.65	183
Wyckoff ditch	West Fork Big Willow creek	May 17, 1889	2	....	736.65	184
Kiwa ditch	Michigan river	May 25, 1889	1	2	738.65	185
Boomerang ditch	Michigan river	May 31, 1889	1	2	739.65	186
Old S. C. ditch	Michigan river	June 1, 1889	7	....	740.65	187
Seneca ditch enlargement	Michigan river	June 1, 1889	1	2	747.65	188
Freeman ditch	McKenzie creek	June 1, 1889	1	....	748.65	189
Ward ditch No. 2	Illinois river	June 7, 1889	.5	....	749.65	190

TABLE

GIVING DITCH DECREES IN IRRIGATION DISTRICT NO. 47, AS PREPARED BY THE SUPERINTENDENT OF IRRIGATION OF WATER DIVISION NO. 1, FROM THE CERTIFIED COPY OF DECREES GOVERNING APPROPRIATIONS IN THE DISTRICT, FURNISHED HIM BY THE CLERK OF THE DISTRICT COURT ISSUING SUCH DECREES. READJUDICATION MARCH 4, 1902. CHRISTIAN A. BENNETT, JUDGE.—Continued.

NAME OF DITCH	Source of Supply	Date	Amount in Second-Feet Decreed to each Priority	Total Amount in Second-Feet Decreed to each Ditch or Canal	Total Amount in Second-Feet Previously Decreed in District	Order of Priority in District
Martin ditch No. 1	Michigan river	June 14, 1889	1	4	750.15	191
Salem ditch	Big Willow creek	June 15, 1889	2	8	751.15	192
Dora ditch	East Willow creek	June 21, 1889	3	6	753.15	193
Poquette ditch	Michigan river	June 21, 1889	1.5	2	758.15	194
Ward ditch No. 1	Illinois river	June 21, 1889	3	....	759.65	195
Hubbard ditch No. 1	Illinois river	June 21, 1889	2	5	762.65	196
Poverty Flat ditch No. 2	South Fork Michigan river	June 21, 1889	10	....	764.65	197
Spaulding ditch	Pinkham creek	June 21, 1889	.5	1.5	765.15	198
Michigan High Line ditch	Michigan river	June 22, 1889	5.5	8	770.65	199
Bona Fide ditch	Canadian river	June 29, 1889	2	6	772.65	200
Coon Creek ditch	Coon creek	June 30, 1889	1	6	774.65	201
Dulaney ditch	Coon creek	June 30, 1889	2.5	....	775.65	202
Ottawa ditch	Illinois river	June 30, 1889	2.5	4	778.15	203

Buckeye ditch	Michigan river	Sept. 11, 1889	3	11	780.65	204
Kermode ditch	Canadian river	Sept. 15, 1889	1.5	....	783.65	205
Gillette ditch No. 2	Clear creek	Sept. 15, 1889	1	....	785.15	206
Lizzie ditch	Elk creek	Sept. 23, 1889	.5	1.5	786.15	207
Pomroy ditch No. 1	Canadian river	Sept. 30, 1889	12	....	786.65	208
Hard Work ditch	Pinkham creek	Sept. 30, 1889	3.5	....	798.65	209
Gillette ditch No. 1	Muddy creek	Oct. 15, 1889	1.5	....	800.15	210
Stevenson No. 4 ditch	Willow creek	Nov. 1, 1889	2.25	8.25	802.35	211
Monroe ditch	Illinois river	Dec. 7, 1889	2.5	6	804.85	212
Carleton ditch	Michigan river	April 20, 1890	3	....	807.35	213
Donelson ditch	Little Willow creek	April 30, 1890	4	10	810.35	214
Michigan High Line ditch	Michigan river	April 30, 1890	8	16	814.35	215
Boyer ditch	Canadian river	April 30, 1890	1.5	....	822.35	216
Hubbard No. 2 ditch	Illinois river	May 1, 1890	3	6	823.85	217
Bona Fide ditch	Canadian river	May 10, 1890	2.5	8.5	826.85	218
Lizzie ditch	Elk creek	May 10, 1890	1.3	2.8	829.35	219
Troublesome ditch	Canadian river	May 15, 1890	3	....	830.65	220
Matthews Eastern ditch	Michigan river	May 16, 1890	2	8	833.65	221
Teller ditch	Jack Creek	May 20, 1890	2	....	835.65	222
No. 1 ditch	Jack creek	May 20, 1890	1	5	837.65	223
Give a Dam Jones ditch	Canadian river	May 20, 1890	4	....	838.65	224
Stevenson No. 2 enlargement	Stevenson ditch No. 2	May 23, 1890	3	....	842.65	225
Ish ditch enlargement	Ish ditch	May 26, 1890	1	....	845.65	226
Poquette ditch	Michigan river	May 27, 1890	1	3	846.65	227
Old S. C. ditch	Michigan river	June 1, 1890	14	21	847.65	228

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GIVING DITCH DECREES IN IRRIGATION DISTRICT NO. 47, AS PREPARED BY THE SUPERINTENDENT OF IRRIGATION OF WATER DIVISION NO. 1, FROM THE CERTIFIED COPY OF DECREES GOVERNING APPROPRIATIONS IN THE DISTRICT, FURNISHED HIM BY THE CLERK OF THE DISTRICT COURT ISSUING SUCH DECREES. READJUDICATION MARCH 4, 1902. CHRISTIAN A. BENNETT, JUDGE.—Continued.

NAME OF DITCH	Source of Supply	Date	Amount in Second-Feet Decreed to each Priority	Total Amount in Second-Feet Decreed to each Ditch or Canal	Total Amount in Second-Feet Previously Decreed in District	Order of Priority in District
Everhard and Baldwin ditch	Illinois river	June 1, 1890	8	18	861.65	229
Wyckoff ditch	Little Willow creek	June 14, 1890	1.5	4	869.65	230
Poverty Flat ditch No. 2	South Fork Michigan river	June 21, 1890	14	24	871.15	231
Upland ditch	Illinois river	July 14, 1890	2	4	885.15	232
Lowland ditch enlargement and extension	Owl creek	July 15, 1890	1	....	887.15	233
Squibob ditch	Michigan river	July 17, 1890	2	8	888.15	234
Poverty Flat ditch	Michigan river	July 17, 1890	10	20	890.15	235
Fernando ditch	Cabin creek	July 26, 1890	2	8	900.15	236
Wales ditch	Michigan ditch	Sept. 30, 1890	6	....	902.15	237
Cleveland ditch	Michigan river	Oct. 15, 1890	12.5	18	908.15	238
Last Chance ditch	Willow creek	May 1, 1891	1.25	....	921.65	239
Kermode ditch	Canadian river	May 25, 1891	3.5	5	922.90	240
Give a Dam Jones ditch	Canadian river	June 17, 1891	2	6	926.40	241

Oklahoma ditch	Illinois river	June 25, 1891	10	....	928.40	242
Novelty ditch	St. Francis creek	June 25, 1891	8	....	938.40	243
Gillette ditch No. 3	Willow creek	June 25, 1891	8	....	946.40	244
Gillette ditch No. 1	Muddy creek	June 25, 1891	1.5	3	954.40	245
Gillette ditch No. 2	Clear creek	June 25, 1891	3	4	955.90	246
Ruction ditch	Michigan river	June 25, 1891	2	5	958.90	247
North Park ditch No. 7	Michigan river	June 25, 1891	6	10	960.90	248
North Park ditch No. 5	Michigan river	June 25, 1891	4	8	966.90	249
Timothy ditch	Pinkham creek	Aug. 1892	1	....	970.90	250
Overland ditch	Michigan river	May 1, 1893	12.5	18.5	971.90	251
Maggie ditch	Allen creek	May 15, 1893	6	9.5	984.40	252
Hubbard ditch	Illinois river	July 4, 1893	8	14	990.40	253
Medicine Bow ditch	Canadian river	Sept. 21, 1893	43	....	998.40	254
Peabody ditch	Willow creek	May 1, 1894	2	9.5	1,041.40	255
Overland ditch	Michigan river	May 1, 1894	9.5	22	1,043.40	256
Stillwater ditch	Canadian river	May 10, 1894	11.3	....	1,052.90	257
Dryer ditch	Illinois river	May 24, 1894	3.6	8.8	1,064.20	258
Capron ditch	Pinkham creek	May 1894	3.75	7.75	1,067.80	259
Spaulding ditch	Pinkham creek	May 1894	3.75	5.25	1,071.55	260
Newport ditch	Pinkham creek	May 1894	4	6	1,075.30	261
Pomroy ditch	Canadian river	June 15, 1894	23.1	35.1	1,079.30	262
Boyce Bros. ditch No. 1	Illinois river	Oct. 16, 1894	9.25	....	1,102.40	263
Oklahoma ditch No. 2	Illinois river	Oct. 19, 1894	9	....	1,111.65	264
Durgin ditch	Pinkham creek	May 1, 1895	6.5	....	1,120.65	265
Curtin ditch	Michigan river	May 15, 1895	24	....	1,127.15	266

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GIVING DITCH DECREES IN IRRIGATION DISTRICT NO. 47, AS PREPARED BY THE SUPERINTENDENT OF IRRIGATION OF WATER DIVISION NO. 1, FROM THE CERTIFIED COPY OF DECREES GOVERNING APPROPRIATIONS IN THE DISTRICT, FURNISHED HIM BY THE CLERK OF THE DISTRICT COURT ISSUING SUCH DECREES. READJUDICATION MARCH 4, 1902. CHRISTIAN A. BENNETT, JUDGE.—Concluded.

NAME OF DITCH	Source of Supply	Date	Amount in Second-Feet Decreed to each Priority	Total Amount in Second-Feet Decreed to each Ditch or Canal	Total Amount in Second-Feet Previously Decreed in District	Order of Priority in District
Matthews ditch	Michigan river	June 15, 1895	4	18	1,151.15	267
Dale ditch	Muddy creek	May 1, 1896	8	....	1,155.15	268
Allard ditch	Pinkham creek	May 9, 1896	5.87	....	1,163.15	269
Ish and Baldwin ditch	Illinois river	May 20, 1896	1.6	....	1,169.02	270
Howard ditch	Willow creek	May 15, 1897	12	20	1,170.62	271
Cumberland ditch	Michigan river	Sept. 10, 1897	24	33	1,182.62	272
Hubbard ditch	Illinois river	Sept. 10, 1897	15	29	1,206.62	273
Ward ditch, Boston extension	Illinois river	Nov. 25, 1897	13	16	1,219.62	274
Curtin ditch	Michigan river	May 15, 1898	16	40	1,235.62	275
Carpenter ditch	Canadian river	June 10, 1898	1.4	2	1,237.02	276
Cameron Pass ditch	Michigan river	July 7, 1898	18	28	1,255.02	277
Dry Creek ditch	Michigan river	Aug. 24, 1898	11.6	....	1,266.62	278
Jay ditch	Jack creek	Sept. 15, 1898	7.2	....	1,273.82	279

Bona Fide ditch	Canadian river	Sept. 15, 1898	1.5	10	1,275.82	280
Dryer ditch	Illinois river	Oct. 1, 1898	2.4	11.2	1,276.82	281
Queen ditch	Michigan river	Oct. 11, 1898	16.25	....	1,279.22	282
Ohio ditch	McKenzie creek	July 10, 1899	3	....	1,295.47	283
Smith ditch	Canadian river	Sept. 15, 1899	21.3	....	1,298.47	284
Pomroy ditch	Canadian river	Sept. 20, 1899	15.6	50.7	1,319.77	285
Midland ditch	Illinois river	Sept. 1, 1900	15	35	1,335.37	286
Old S. C. ditch	Michigan river	Oct. 1, 1900	32.5	33.5	1,350.37	287
Hi Ho ditch	Michigan creek	April 25, 1901	12	18	1,382.87	288
Carleton ditch	Michigan river	May 5, 1901	4.5	8.5	1,394.87	289
Squibob ditch	Michigan river	May 14, 1901	27	35	1,399.37	290
Oldenburg ditch	Jack creek	May 15, 1901	2.5	....	1,426.37	291
Everhard and Baldwin ditch	Illinois river	May 15, 1901	7	25	1,428.87	292
Walden ditch No. 3	Michigan river	July 13, 1901	12	....	1,435.87	293

TABLE

GIVING DITCH DECREES IN IRRIGATION DISTRICT NO. 46, AS PREPARED BY THE SUPERINTENDENT OF IRRIGATION OF WATER DIVISION NO. 1, FROM THE CERTIFIED COPY OF THE DECREES GOVERNING APPROPRIATIONS IN THE DISTRICT, FURNISHED HIM BY THE CLERK OF DISTRICT COURT ISSUING SUCH DECREES. READJUDICATION MARCH 4, 1902. CHRISTIAN A. BENNETT, JUDGE.

NAME OF DITCH	Source of Supply	Date	Amount in Second-Feet Decreed to each Priority	Total Amount in Second-Feet Decreed to each Ditch or Canal	Total Amount in Second-Feet Previously Decreed in District	Order of Priority in District
Little Grizzly ditch	Little Grizzly river	May 7, 1881	2.5	....	....	1
Peterson ditch No. 1	Big Grizzly river	June 1, 1882	6	....	2.5	2
Marr ditch No. 1	Little Grizzly river	Aug. 13, 1883	9	....	8.5	3
Koping ditch No. 1	Big Grizzly river	May 1, 1883	4.5	....	17.5	4
Newcomb ditch	Little Grizzly river	May 31, 1883	2	....	22	5
Little Grizzly ditch	Little Grizzly river	May 31, 1883	8	10.5	24	6
Peterson ditch No. 2	Big Grizzly river	July 1, 1883	4.5	....	32	7
Chedsey ditch No. 1	Skull creek	July 1, 1883	1	....	36.5	8
Peterson ditch No. 1	Big Grizzly river	May 20, 1884	3.5	9.5	37.5	9
West Fork ditch	North Fork Platte river	May 29, 1884	12	....	41	10
Badger State ditch	Coyote creek	June 20, 1884	5	....	53	11
Timber ditch	Hell creek	Oct. 1, 1884	1.5	....	58	12
Newcomb ditch	Little Grizzly river	Dec. 20, 1884	.5	2.5	59.5	13

East Buffalo ditch	Buffalo creek	April 30, 1885	1.5	....	60	14
Nairn ditch	Little Grizzly river	May 1, 1885	14.5	....	61.5	15
Damfino ditch	Big Grizzly river	May 15, 1885	2.5	....	76	16
Alexis ditch No. 1	Coyote creek	June 1, 1885	7.5	....	78.5	17
Arapahoe ditch	Arapahoe creek	June 1, 1885	8	....	86	18
Addison ditch	Buffalo creek	June 15, 1885	5	....	94	19
Boulder ditch	Lone Tree creek	June 15, 1885	1	....	99	20
Jennie ditch	Little Grizzly river	June 23, 1885	5	....	100	21
Butler ditch	Beaver creek	July 5, 1885	2	....	105	22
Chedsey ditch No. 1	Skull creek	July 31, 1885	3	4	107	23
Lawrence ditch No. 2	Arapahoe creek	April 26, 1886	2	....	110	24
Big Grizzly ditch	Big Grizzly river	April 30, 1886	10	....	112	25
Little Nellie ditch	North Fork North Platte river	April 30, 1886	3.5	....	122	26
Edith ditch	Cheyenne creek	May 1, 1886	7.5	....	125.5	27
West Buffalo ditch	Buffalo creek	May 25, 1886	6	....	133	28
Spicer ditch	Big Grizzly river	May 31, 1886	2	....	139	29
Chapman ditch	North Fork Little Grizzly river	May 31, 1886	4	....	141	30
Damfino ditch	Big Grizzly river	June 30, 1886	2.5	5	145	31
West Fork ditch	North Fork Platte river	Aug. 31, 1886	7	19	147.5	32
969 ditch	Big Grizzly river	April 1, 1887	2	....	154.5	33
Dalom ditch	North Platte river	April 15, 1887	2.5	....	156.5	34
Lawrence ditch No. 1	Arapahoe creek	April 15, 1887	5	....	159	35
Lorena ditch	North Platte river	April 15, 1887	4	....	164	36
Cochrane ditch	Coyote creek	April 20, 1887	2	....	168	37
Little Nellie ditch	North Fork North Platte river	April 30, 1887	14	17.5	170	38

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GIVING DITCH DECREES IN IRRIGATION DISTRICT NO. 46, AS PREPARED BY THE SUPERINTENDENT OF IRRIGATION OF WATER DIVISION NO. 1, FROM THE CERTIFIED COPY OF THE DECREES GOVERNING APPROPRIATIONS IN THE DISTRICT, FURNISHED HIM BY THE CLERK OF DISTRICT COURT ISSUING SUCH DECREES. READJUDICATION MARCH 4, 1902. CHRISTIAN A. BENNETT, JUDGE.—Continued.

NAME OF DITCH	Source of Supply	Date	Amount in Second-Feet Decreed to each Priority	Total Amount in Second-Feet Decreed to each Ditch or Canal	Total Amount in Second-Feet Previously Decreed in District	Order of Priority in District
Marr ditch No. 2	Little Grizzly river	May 1, 1887	10	....	184	39
Darling ditch	Little Grizzly river	May 1, 1887	8	....	194	40
Dora ditch	Cheyenne creek	May 1, 1887	5	....	202	41
Mellen ditch	Buffalo creek	May 3, 1887	2.5	....	207	42
Willow ditch	Arapahoe creek	May 5, 1887	6	....	209.5	43
Seymour ditch No. 2	Big Grizzly river	May 10, 1887	1.5	....	215.5	44
Antelope ditch	Little Grizzly river	May 15, 1887	3.5	....	217	45
Butler ditch No. 4	Cheyenne creek	May 15, 1887	2.5	....	220.5	46
Moore ditch No. 4	Roaring Fork	May 15, 1387	3.5	....	223	47
Arapahoe ditch	Arapahoe creek	May 15, 1887	11	18.5	226.5	48
Poled Angus ditch	Buffalo creek	May 17, 1887	4	....	237.5	49
Chapman ditch	North Fork Little Grizzly river	May 31, 1887	2	6	241.5	50
Butler ditch No. 2	Cheyenne creek	June 1, 1887	1.5	....	243.5	51

Timber ditch	Hell creek	June 5, 1887	2.5	4	245	52
Castle ditch	Big Grizzly river	June 15, 1887	2.5	....	247.5	53
Burke ditch	Buffalo creek	June 15, 1887	3.5	....	250	54
Ellen ditch	North Platte river	June 15, 1887	2.5	....	253.5	55
Little Grizzly ditch	Little Grizzly river	Sept. 1, 1887	14.5	25	256	56
Eureka ditch	Arapahoe creek	Sept. 8, 1887	70	....	270.5	57
Wisconsin ditch	Buffalo creek	Sept. 10, 1887	7.5	....	340.5	58
Slack ditch	Buffalo creek	April 15, 1888	9	....	348	59
Dalom ditch	North Platte river	April 15, 1888	5.5	8	357	60
Mallon ditch	Roaring Fork	April 20, 1888	24	....	362.5	61
Van Patten ditch	Buffalo creek	April 20, 1888	3	....	386.5	62
Lone Pine ditch	Lone Pine creek	May 1, 1888	15	....	389.5	63
Wolfer ditch	Roaring Fork	May 8, 1888	6	....	404.5	64
Staples ditch No. 1	Little Grizzly river	May 10, 1888	10	....	410.5	65
Clifton ditch	Buffalo creek	May 15, 1888	2	....	420.5	66
Butler ditch No. 2	Cheyenne creek	May 15, 1888	1	2.5	422.5	67
Butler ditch	Beaver creek	May 25, 1888	2.5	....	423.5	68
Newcomb ditch	Little Grizzly river	May 31, 1888	12.5	15	426	69
Spicer ditch	Big Grizzly river	May 31, 1888	10	12	438.5	70
Forest ditch	Lost creek	June 1, 1888	.5	....	448.5	71
Mitchell ditch	Cheyenne creek	June 10, 1888	8	....	449	72
Boone ditch	North Platte river	June 14, 1888	10	....	457	73
Nile ditch	North Platte river	June 15, 1888	8	....	467	74
Boulder ditch	Lone Tree creek	June 15, 1888	7	8	475	75
Lorena ditch	North Platte river	July 16, 1888	3.5	7.5	482	76

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GIVING DITCH DECREES IN IRRIGATION DISTRICT NO. 46, AS PREPARED BY THE SUPERINTENDENT OF IRRIGATION OF WATER DIVISION NO. 1, FROM THE CERTIFIED COPY OF THE DECREES GOVERNING APPROPRIATIONS IN THE DISTRICT, FURNISHED HIM BY THE CLERK OF DISTRICT COURT ISSUING SUCH DECREES. READJUDICATION MARCH 4, 1902. CHRISTIAN A. BENNETT, JUDGE.—Continued.

NAME OF DITCH	Source of Supply	Date	Amount in Second-Feet Decreed to each Priority	Total Amount in Second-Feet Decreed to each Ditch or Canal	Total Amount in Second-Feet Previously Decreed in District	Order of Priority in District
Mutual ditch	Big Grizzly river	Aug. 29, 1888	100	....	485.5	77
Independent ditch	North Fork North Platte river	Sept. 1, 1888	35.75	....	585.5	78
Mammoth ditch	North Platte river	Sept. 1, 1888	14.8	....	621.25	79
Mitchell ditch	Cheyenne creek	Sept. 10, 1888	7	15	636.05	80
Mallon ditch	Roaring Fork	Oct. 31, 1888	13.5	37.5	643.05	81
New Ross ditch	....	Mar. 23, 1889	9	....	656.55	82
Mar Ditch No. 1	Little Grizzly river	Mar. 25, 1889	8.5	17.5	665.55	83
Spicer ditch enlargement and extension	Little Grizzly river	Mar. 31, 1889	8	....	674.05	84
Bennett and Leshner ditch	Little Grizzly river	April 2, 1889	13	....	682.05	85
Hogdson ditch	Cheyenne creek	April 10, 1889	5	....	695.05	86
Staples ditch enlargement and extension	Little Grizzly river	April 15, 1889	20	....	700.05	87
Higho ditch	Roaring Fork	April 18, 1889	2.5	....	720.05	88
Erika ditch	Lone Pine creek	May 1, 1889	11.75	....	722.55	89

Larson ditch	Big Grizzly river	May 10, 1889	4	....	734.25	90
Antelope ditch	Little Grizzly river	May 10, 1889	8.5	12	738.25	91
Earnest ditch	Cheyenne creek	May 15, 1889	2.5	....	746.75	92
Victor ditch	North Fork Platte river	May 20, 1889	19.5	....	749.25	93
Seymour ditch No. 1	Big Grizzly river	May 25, 1889	3	....	768.75	94
Legal Tender ditch	North Fork Platte river	June 1, 1889	7	....	771.75	95
Luckpenny ditch	Beaver creek	June 1, 1889	15	....	778.75	96
Chedsey ditch No. 2	South Fork Little Grizzly river	June 3, 1889	3	....	793.75	97
Norris ditch	South Fork Roaring Fork	June 10, 1889	2.5	....	796.75	98
Reithmeyer ditch	North Fork North Platte river	June 20, 1889	5	....	799.25	99
Jennie ditch	Little Grizzly river	June 23, 1889	7	12	804.25	100
Koping ditch	Big Grizzly river	Sept. 25, 1889	2	6.5	811.25	101
Roaring ditch	South Fork North Platte river	Oct. 7, 1889	5	....	813.25	102
Pleasant Valley ditch	North Fork Platte river	Oct. 18, 1889	36	....	818.25	103
Davis ditch	North Platte river	April 1, 1890	4.4	....	854.25	104
Higho ditch	Roaring Fork river	May 6, 1890	2	....	858.65	105
Staples ditch, enlarged and extended	Little Grizzly river	May 15, 1890	5	....	860.65	106
Roaring ditch	South Fork North Platte river	May 15, 1890	33.25	....	865.65	107
Staples ditch No. 2	Little Grizzly river	June 1, 1890	15	....	898.85	108
Boulder ditch	Lone Tree creek	June 1, 1890	12	20	913.85	109
Legal Tender ditch	North Fork Platte river	June 1, 1890	10	....	925.85	110
Chedsey ditch No. 2	South Fork Little Grizzly river	June 3, 1890	2	....	935.85	111
Clayton ditch	Buffalo creek	June 8, 1890	.8	....	937.85	112
Norris ditch	South Fork Roaring Fork	June 10, 1890	2.5	....	938.65	113
Briggs ditch	Lone Pine creek	June 15, 1890	5	....	941.15	114

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GIVING DITCH DECREES IN IRRIGATION DISTRICT NO. 46, AS PREPARED BY THE SUPERINTENDENT OF IRRIGATION OF WATER DIVISION NO. 1, FROM THE CERTIFIED COPY OF THE DECREES GOVERNING APPROPRIATIONS IN THE DISTRICT, FURNISHED HIM BY THE CLERK OF DISTRICT COURT ISSUING SUCH DECREES. READJUDICATION MARCH 4, 1902. CHRISTIAN A. BENNETT, JUDGE.—Concluded.

NAME OF DITCH	Source of Supply	Date	Amount in Second-Feet Decreed to each Priority	Total Amount in Second-Feet Decreed to each Ditch or Canal	Total Amount in Second-Feet Previously Decreed in District	Order of Priority in District
Little Nellie ditch	North Fork North Platte river	June 15, 1890	70	87.5	946.15	115
Chapman ditch	North Fork Little Grizzly river	June 19, 1890	5	11	1,016.15	116
Forest ditch	Lost creek	Aug. 31, 1890	2	2.5	1,021.15	117
Buckeye ditch	Little Grizzly river	Sept. 30, 1890	10	....	1,023.15	118
Homestead ditch	Big Grizzly river	April 24, 1891	11.25	....	1,033.15	119
Sunday Creek ditch	Sunday creek	May 10, 1891	4	....	1,044.40	120
Lillie ditch	Lone Pine creek	June 1, 1891	15	....	1,048.40	121
Chapman ditch	North Fork Little Grizzly river	June 1, 1891	16	27	1,063.40	122
Stormy ditch	No Name creek	Oct. 15, 1891	8	....	1,079.40	123
Victor ditch	North Fork Platte river	April 25, 1892	3	....	1,087.40	124
Jordan ditch	Arapahoe creek	June 1, 1893	4.6	....	1,090.40	125
Big Grizzly ditch	Big Grizzly river	Aug. 1, 1893	20	30	1,095	126
Forest ditch	Lost creek	May 15, 1894	3.2	5 7	1,115	127

Hillside ditch	Lone Pine creek	May 15, 1895	15	....	1,118.2	128
Sunday Creek ditch	Sunday creek	April 20, 1896	8	....	1,133.2	129
Castle ditch	Big Grizzly river	April 25, 1896	9	11.5	1,141.2	130
Chedsey ditch No. 2	South Fork Little Grizzly river	April 1, 1898	9.5	....	1,150.2	131
Staples ditch No. 2	Little Grizzly river	May 13, 1898	14.4	....	1,159.7	132
Heineman ditch	North Fork Roaring Fork	May 15, 1898	6.3	....	1,174.1	133
Boone ditch	North Platte river	Sept. 15, 1898	9	....	1,180.4	134
Mallon ditch No. 2	Roaring Fork	April 15, 1900	80	....	1,189.4	135
Mitchell ditch	Cheyenne creek	May 1, 1901	16.75	31.75	1,270.15	136

TABLE

GIVING ADDITIONAL DITCH DECREES IN WATER DISTRICT NO. 8, AS THEY HAVE BEEN ESTABLISHED SINCE THE STATEMENT PUBLISHED IN THE "TENTH BIENNIAL REPORT," PREPARED BY THE SUPERINTENDENT OF IRRIGATION OF WATER DIVISION NO. 1, FROM THE CERTIFIED COPY OF THE DECREES GOVERNING APPROPRIATIONS IN THIS DISTRICT, FURNISHED HIM BY THE CLERK OF THE DISTRICT COURT ISSUING SUCH DECREES.

NAME OF DITCH OR CANAL.	Source of Appropriation	Date	Amount in Second-Feet Decreed to each Priority	Order of Priority in District
The James ditch	West Plum creek	Jan. 1, 1883	2	139
Schultz ditch	Russelville Branch Cherry creek	Jan. 1, 1883	2	140
Eureka ditch	East Plum creek	Mar. 31, 1883	7	141
Ratcliff and Dillon ditch	Spring creek	Mar. 31, 1883	3	142
Herzog ditch	Cherry creek	Sept. 10, 1883	3.5	143
Rowley ditch	Cherry creek	Mar. 31, 1884	4	144
Hawkey ditch	Cherry creek	Aug. 25, 1884	3	145
Parker ditch	Cherry creek	Jan. 1, 1885	3	146
Barnes ditch	Cherry creek	Mar. 31, 1885	4.5	147
Parker ditch No. 2	Cherry creek	Mar. 31, 1885	3	148
Gregg ditch	Cherry creek	Mar. 31, 1885	14	149
John Kinner ditch No. 2	West Plum creek	April 1, 1885	3.5	150
Glen Cove Feeder ditch	West Plum creek	Sept. 10, 1885	7	151

Locust Grove ditch	Indian creek	May 3, 1886	3	152
Green Meadow ditch	Indian creek	May 15, 1886	2.79	153
Sellars Gulch ditch	Sellars Gulch creek	May 18, 1886	2.5	154
Bauldorf ditch	Cherry creek	Mar. 31, 1886	6	155
Upton T. Smith ditch and reservoirs	Spring creek	Aug. 15, 1886	....	156
Melvin ditch and reservoir	Cherry creek	Feb. 17, 1887	12	157
The Stevens Jackson creek ditch	Jackson creek	Mar. 1, 1887	6	158
Feeder of Stevens reservoir	West Plum creek	May 1, 1888	....	159
Lambert feeder and reservoir	Indian creek	Feb. 9, 1888	10	160
King ditch	East Plum creek	Feb. 23, 1888	2	161
Middleton ditch	West Plum creek	Mar. 3, 1888	7	162
Waucondah reservoir	Bear Springs creek	Sept. 1, 1888	....	163
West Plum creek bottom ditch and reservoir	West Plum creek	Oct. 1, 1888	....	164
Castlewood reservoir	Cherry creek	Sept. 1, 1889	....	166
Arapahoe ditch	Cherry creek	Sept. 1, 1889	....	167
Rock Ridge ditch	Cherry creek	Sept. 3, 1892	3	172
Conehay ditch	Cherry creek	Aug. 19, 1892	4.5	173
Castle Rock water works pipe line	East Plum creek	Aug. 30, 1893	3.46	176

CHAPTER VI.

SEEPAGE MEASUREMENTS.

Fort Collins, Colo., October 27, 1902.

A. J. McCune,
State Engineer, Denver, Colo.

Dear Sir: For a number of years the experiment station has made measurements of the loss or increase of various streams in the state from seepage, as well as various canals. A report was prepared and issued in 1896 as Bulletin No. 33 by the experiment station on "Seepage or Return Waters," which was more especially confined to the Cache la Poudre and the Platte rivers, which had been the subject of measurements up to that time. Since then the measurements have been extended noticeably to the Arkansas and the Rio Grande. More recently the work has been extended to include the tributaries of the Platte, and also the Uncompahgre. In a portion of this work your office has helped by paying a part of the expenses. Much aid has been received from water commissioners in various parts of the state.

The method of measurement has been essentially to treat each section of the stream independently of the section above or below, that is, a measurement would be made of the stream and the water being taken out by ditches and the water entering by streams was measured. The original canal increase by the inflow and diminish by outflow would indicate the amount that would be expected at the next measurement, provided there were no losses or gains. The excess or defect of the next measurement as compared with this sum would show the increase or decrease of the river due to seepage. In the progress of the measurements now carried on for over twelve years some modifications shown by exper-

ience to be necessary all leading to greater care have been introduced, though the method and principle remains the same as at first.

The following is a summary of the results of measurements made in 1901 and 1902. It is found that the measurements of the same section do not exactly agree at different times. This is to be expected, as the amount of inflow undoubtedly varies, according to the condition of the situation, the condition of the soil, the temperature, and various other conditions. In addition to this, it has been difficult to eliminate the effect of fluctuation in the river itself, though the method of procedure is such as to generally detect the quantity in great disturbances from these sources. It is also undoubtedly the case that at times some discrepancies have been introduced by the fluctuation in the inflow of canals. Through the co-operation of water commissioners this is generally reduced to a minimum or entirely excluded.

Very truly yours,

L. G. CARPENTER.

CACHE LA POUDRE, 1901.

	River		Section Gain or Loss	Total Gain or Loss
	Inflow	Outtake		
From gaging station in canon to Fort Collins water works	331.22	328.54	—2.88	—2.88
Larimer and Weld canal	126.74	153.47	26.73	+23.85
No. 2 reservoir supply	113.70	122.14	8.44	+32.29
Box Elder ditch	76.36	84.83	8.47	40.76
Strauss bridge	106.40	103.74	—2.66	38.10
No. 2 canal	80.41	74.21	—6.20	31.90
Eaton ditch	105.72	171.96	6.24	38.14
Greeley No. 3	215.80	235.76	19.96	58.10
Mill power canal	5.85	34.22	28.37	86.47
Camp ditch	25.22	61.09	35.87	122.34
Near mouth	....	44.96	44.96	167.30

CACHE LA POUDRE, 1902.

	River		Section Gain or Loss	Total Gain or Loss
	Inflow	Outtake		
From gaging station in canon to Fort Collins water works	304.00	295.18	—8.82	—8.82
Larimer and Weld canal	90.32	103.24	12.92	+4.10
No. 2 reservoir supply	81.95	85.18	3.23	+7.33
Box Elder ditch	65.88	72.12	6.24	+13.37
Strauss ditch	78.02	82.98	4.96	+18.53
No. 2 canal	66.74	70.42	3.68	+22.21
Eaton ditch	70.28	75.26	4.98	+29.19
Greeley No. 3	42.93	63.45	20.52	+47.71
Pump house	3.65	24.33	20.68	+68.39
Camp ditch	15.09	37.02	21.93	+90.32
Near mouth	....	29.11	29.11	+119.43

MASONRY DAM AT LAKE CHEESMAN, COLORADO.

BOULDER CREEK, AUGUST, SEPTEMBER, 1901.

	River		Section Gain or Loss	Total Gain or Loss
	Inflow	Outtake		
Gaging station to Valmont	59.68	72.46	12.78	12.78
Leggits Crossing	26.98	29.31	2.33	15.11
Boulder and Weld county line	30.69	33.57	2.88	17.99
Near mouth	16.40	14.60	—1.80	16.19

BOULDER CREEK, SEPTEMBER, 1902.

	River		Section Gain or Loss	Total Gain or Loss
	Inflow	Outtake		
Gaging station to Valmont	18.89	25.11	6.23	6.23
Leggits Crossing	14.84	9.96	4.88	11.11
Boulder and Weld county line	.23	1.44	1.21	12.32
Near mouth	1.30	1.46	.16	12.48

CLEAR CREEK, SEPTEMBER, 1901.

	River		Section Gain or Loss	Total Gain or Loss
	Inflow	Outtake		
Three-fourth mile above Golden to Rocky Mountain ditch	144.27	145.71	1.44	1.44
Head of slough	60.23	57.08	3.15	1.71
Mouth of slough	50.92	60.88	9.96	8.25
Clear Creek and Platte River ditch	39.85	54.37	14.52	22.77
Near mouth	1.36	2.83	1.47	24.24

CLEAR CREEK, SEPTEMBER, 1902.

	River		Section Gain or Loss	Total Gain or Loss
	Inflow	Outtake		
Three-fourth mile above Golden to Rocky Mountain ditch	74.42	77.95	3.53	3.53
Head of slough	1.35	1.97	.62	4.15
Mouth of slough	3.02	6.40	3.38	7.53
Clear Creek and Platte River ditch	2.91	4.00	1.09	8.62
Near mouth	....	.16	.16	8.78

BEAR CREEK, SEPTEMBER, 1901.

	River		Section Gain or Loss	Total Gain or Loss
	Inflow	Outtake		
Ward and Kendrick ditch to Pioneer Union	17.22	21.99	4.77	4.77
Jefferson-Arapahoe county line	....	8.66	8.66	13.43
Near mouth	5.67	10.94	5.27	18.70

BEAR CREEK, SEPTEMBER, 1902.

	River		Section Gain or Loss	Total Gain or Loss
	Inflow	Outtake		
Ward irrigating canal to Pioneer Union	.55	1.09	.54	.54
Jefferson-Arapahoe county line	.16	3.31	3.15	3.69
Near mouth	.78	1.24	.46	4.15

ST. VRAIN CREEK, JULY AND AUGUST, 1901.

	River		Section Gain or Loss	Total Gain or Loss
	Inflow	Outtake		
Lyons to Oligarchy ditch	272.18	243.21	—28.97	—28.97
Below Niwot ditch	58.25	65.42	7.17	21.80
Boulder and Weld county line	74.13	95.30	21.17	—.63
Boulder creek	67.75	76.37	8.62	8.99
Fleming bridge	76.11	104.72	28.61	36.60
Near mouth	89.55	81.69	—7.86	28.74

ST. VRAIN CREEK, AUGUST, 1902.

	River		Section Gain or Loss	Total Gain or Loss
	Inflow	Outtake		
Lyons to Oligarchy ditch	69.48	64.87	—4.61	—4.61
Below Niwot ditch	.85	3.59	2.74	—1.87
Boulder and Weld county line	2.13	5.56	3.43	1.56
Boulder creek	4.83	10.16	5.33	6.89
Fleming bridge	11.46	14.34	2.88	9.77
Near mouth	6.36	9.97	3.61	13.38

BIG THOMPSON, SEPTEMBER AND JULY, 1901.

	River		Section Gain or Loss	Total Gain or Loss
	Inflow	Outtake		
Home supply dam to Langston	15.12	15.33	.21	.21
Loveland and Greeley canal	220.45	233.44	12.99	13.20
Lytle bridge	187.26	179.13	—8.13	5.07
Below hill and Brush ditch	4.60	16.05	11.45	16.52
Big Thompson and Platte river ditch	12.62	29.68	17.06	33.58
Evans town ditch	10.60	30.67	20.07	53.65

BIG THOMPSON, JULY, 1902.

	River		Section Gain or Loss	Total Gain or Loss
	Inflow	Outtake		
Home supply dam to Langston	57.87	64.51	6.64	6.64
Loveland and Greeley canal	65.98	68.24	2.26	8.90
Lytle bridge	113.23	124.46	11.21	20.11
Below hill and Brush ditch	2.46	4.41	1.95	22.06
Big Thompson and Platte river ditch	3.39	15.18	11.79	33.85
Evans town ditch	5.88	14.12	8.24	42.09

LITTLE THOMPSON CREEK, JULY, 1901.

	River		Section Gain or Loss	Total Gain or Loss
	Inflow	Outtake		
Eagle ditch to Dry creek	.38	5.40	5.02	5.02
Rockwell bridge	2.46	7 06	4.60	9.62
Minor and Langdon	2.01	6.12	4.11	13.73
Graham bridge	....	7.69	7.69	21.42
Near mouth	7.69	14.51	6.82	28.24

LITTLE THOMPSON CREEK, AUGUST, 1902.

	River		Section Gain or Loss	Total Gain or Loss
	Inflow	Outtake		
Eagle ditch to Dry creek	....	1.41	1.41	1.41
Rockwell bridge	.69	2.81	2.12	3.53
Minor and Langdon	.93	1.55	.62	4.15
Graham bridge	....	6.41	6.41	10.56
Near mouth	6.41	10.58	4.17	14.73

UNCOMPAHGRE RIVER, OCTOBER, 1901.

	River		Section Gain or Loss	Total Gain or Loss
	Inflow	Outtake		
Bachelor mine switch to eleventh correction line	34.19	33.50	—.69	—.69
Ridgway	10.87	44.02	33.15	33.84
Seven miles below Ridgway	72.76	86.43	13.67	47.51
Ouray-Montrose county line	87.00	81.25	—5.75	41.76
Stark bridge	68.41	74.25	15.84	57.60
Montrose	29.18	36.14	6.96	64.56
Spring creek	9.03	42.79	33.76	98.32
Olathe	22.87	33.50	10.63	108.95
Boles and Manny ditch	12.40	19.51	7.11	116.06
Delta bridge	....	22.18	22.18	138.24

UNCOMPAHGRE RIVER, NOVEMBER, 1902.

	River		Section Gain or Loss	Total Gain or Loss
	Inflow	Outtake		
Bachelor mine switch to eleventh correction line	38.00	44.91	6.91	6.91
Ridgway	32.67	50.60	18.23	25.14
Seven miles below Ridgway	91.51	105.77	14.26	39.40
Ouray-Montrose county line	108.33	97.31	11.02	28.38
Stark bridge	90.23	110.30	18.90	47.28
Montrose	21.00	26.44	5.44	52.72
Spring creek	2.48	32.81	30.33	83.05
Olathe	14.22	23.81	9.59	92.64
Boles and Manny ditch	.72	2.67	1.95	94.59
Delta bridge	....	13.41	13.41	108.00

SOUTH PLATTE SEEPAGE, 1901.

NAME OF STREAM	Amount in River	Amount Removed	Amount Entering	Amount in River +Outtake and —Inflow in Preceding Section	Increase in Section	Decrease in Section	Increase or Decrease per mile	Total Increase from Canon	Date	Remarks
High Line canal		79.60							Oct. 7	
South Platte river	77.72								Oct. 7	Mouth of canon
Platte Canon ditch		24.77							Oct. 7	
Last Chance ditch		14.13							Oct. 7	
City ditch		44.94							Oct. 7	
Waste			1.00						Oct. 7	
South Platte river	16.10			98.94	21.22		6—3.54	21 22	Oct. 7	Haworth bridge
Deer creek			16.38						Oct. 8	
South Platte river	43.97			27.59	11.49		6—1.91	32.71	Oct. 8	Littleton
South Platte river	79.60				35.63		10—3.56	68.34	Oct. 8	Fifteenth street, Denver
Denver city waste			60.00						Oct. 9	Estimated
Farmers' and Gardeners' ditch		5.09							Oct. 9	
Clear creek			.50						Oct. 9	
Fulton ditch		109.28							Oct. 9	
South Platte river	47.45			101.32	21.72		11—1.97	90.06	Oct. 9	Below Fulton dam
Brantner ditch		37.40							Oct. 10	

SOUTH PLATTE SEEPAGE, 1901—Continued.

NAME OF STREAM	Amount in River	Amount Removed	Amount Entering	Amount in River +Outtake and —Inflow in Preceding Section	Increase in Section	Decrease in Section	Increase or Decrease per mile	Total Increase from Canon	Date	Remarks
Brighton ditch	....	16.75	....	....	....	....	....	....	Oct. 10	....
South Platte river	44.87	....	....	99.02	51.57	....	7—7.37	141.63	Oct. 10	Brighton
McCann Seepage ditch	....	10.72	....	....	....	....	....	....	Oct. 10	....
Lupton bottom ditch	....	22.32	....	....	....	....	....	....	Oct. 10	....
Platteville ditch	....	19.52	....	....	....	....	....	....	Oct. 10	....
South Platte river	76.20	....	....	128.76	83.89	....	8—10.49	225.52	Oct. 10	Platteville dam
Evans No. 2 ditch	....	57.96	....	....	....	....	....	....	Oct. 11	....
Meadow Island ditch	....	6.86	....	....	....	....	....	....	Oct. 11	....
Farmers' independent ditch	....	58.16	....	....	....	....	....	....	Oct. 11	....
South Platte river	....	....	....	122.98	46.78	....	8—5.85	272.30	Oct. 11	Platteville
Cook and Hewes ditch	....	19.67	....	....	....	....	....	....	Oct. 11	....
St. Vrain creek	....	....	44.21	....	....	....	....	....	Oct. 11	....
Union ditch	....	63.44	....	....	....	....	....	....	Oct. 11	....
South Platte river	20.55	....	....	59.45	59.45	....	9—6.61	331.75	Oct. 11	Below Union Gates
Big Thompson river	....	....	11.54	....	....	....	....	....	Oct. 12	....
Section No. 3 ditch	....	12.78	....	....	....	....	....	....	Oct. 12	....
Lower Latham ditch	....	67.27	....	....	....	....	....	....	Oct. 12	....

South Platte river	31.43			99.94	79.39		7½–10.59	411.14	Oct. 12	Lower Evans bridge
Cache la Poudre river			98.84						Oct. 14	
Sterling Seepage ditch		3.96							Oct. 14	
South Platte river	299.17			204.29	172.86		9–19.21	• 584.00	Oct. 14	Below head Hoover dam
Illinois ditch		1.82							Oct. 14	
Hardin ditch		3.00							Oct. 14	
Box Elder creek			8.03						Oct. 14	
Putnam ditch		13.72							Oct. 15	
South Platte river	298.04			308.55	9.38		17—.55	593.38	Oct. 15	Below head Putnam
Weldon Valley ditch		48.06							Oct. 15	
South Platte river	275.91			323.97	25.93		8½—3.05	619.31	Oct. 16	Orchard
Fort Morgan canal		256.37							Oct. 16	
South Platte river	16.10			272.47		3.44	9—.38	615.87	Oct. 16	Weldon-Shafer's ford
Deuel and Snyder ditch		3.78							Oct. 16	
Platt ditch		7.74							Oct 16	
Upper Platte and Beaver ditch		69.98							Oct. 17	
South Platte river	3.00			84.50	68.40		9–7.60	684.27	Oct. 16	Fort Morgan
Cooper ditch		11.86							Oct. 17	
A. A. Smith ditch		10.48							Oct. 17	
South Platte river	46.53			68.87	65.87		11—5.99	750.14	Oct. 17	Snyder
Tetsel ditch		17.39							Oct. 18	
Johnson and Edwards ditch		23.31							Oct. 18	
South Platte ditch		42.56							Oct. 18	
Davis Bros. ditch		26.11							Oct. 18	
South Platte river	34.20			143.57	97.04		18—5.38	847.18	Oct. 18	Merino

SOUTH PLATTE SEEPAGE, 1901—Concluded.

NAME OF STREAM	Amount in River	Amount Removed	Amount Entering	Amount in River + Outtake and —Inflow in Preceding Section	Increase in Section	Decrease in Section	Increase or Decrease per mile	Total Increase from Canon	Date	Remarks
Snyder ditch	....	6.27	....	....	....	....	....	....	Oct. 19	....
Smith and Henderson ditch	....	7.89	....	....	....	....	....	....	Oct. 19	....
South Platte river	67.04	....	....	81.20	47.00	....	13½—3.42	894.18	Oct. 19	Sterling
Bravo ditch	....	65.02	....	....	....	....	....	....	Oct. 20	....
J. B. ditch	....	10.57	....	....	....	....	....	....	Oct. 20	....
South Platte river	23.49	....	....	99.08	32.04	....	11½—2.73	926.22	Oct. 20	Iliff
South Platte river	35.61	....	....	....	12.12	....	17—.71	938.34	Oct. 21	Crook
Settler's ditch	....	17.28	....	....	....	....	....	....	Oct. 21	....
Peterson ditch	....	10.67	....	....	....	....	....	....	Oct. 22	....
Lodge Pole creek	....	....	10.74	....	....	....	....	....	Oct. 22	....
South Platte river	22.13	....	....	39.34	3.73	....	30—.12	942.07	Oct. 22	Julesburg

SOUTH PLATTE SEEPAGE, 1902.

NAME OF STREAM	Amount in River	Amount Removed	Amount Entering	Amount in River + Outtake and —Inflow in Preceding Section	Increase in Section	Decrease in Section	Increase or Decrease per mile	Total increase from Canon	Date	Remarks
South Platte river	59.01								Oct. 27	Above Water Co. intake
Denver Water Co. pipe		19.92							Oct. 27	
Highline Canal		3.10							Oct. 27	
Denver Water Co. ditch		19.49							Oct. 27	
South Platte river	16.67			59.18	.17		3—.05		Oct. 27	Mouth of Canon
Platte Canon ditch		1.60							Oct. 27	
Last Chance ditch		1.72							Oct. 27	
City ditch		15.33							Oct. 27	
South Platte river	2.89			21.54	4.87		6—.81	5.04	Oct. 27	Haworth bridge
Deer creek			1.29						Oct. 27	
Nevada ditch		1.43							Oct. 28	
South Platte river	15.99			16.13	13.24		6—2.21	18.28	Oct. 28	Littleton
Bear creek			4.20						Oct. 28	
Clark gulch			1.47						Oct. 28	
Cherry creek			1.04						Oct. 28	
South Platte river	47.60			40.89	24.90		10—2.49	43.18	Oct. 28	Denver—16th street
South Platte river	41.60								Oct. 29	Denver—16th street

SOUTH PLATTE SEEPAGE, 1902—Continued.

NAME OF STREAM	Amount in River	Amount Removed	Amount Entering	Amount in River + Outtake and — Inflow in Preceding Section	Increase in Section	Decrease in Section	Increase or Decrease per mile	Total Increase from Canon	Date	Remarks
Farmers' and Gardeners' ditch		4.87							Oct. 29	
Farmers' and Gardeners' waste			.91						Oct. 29	
Denver City sewage			40.00						Oct. 30	
Dougan ditch		1.50							Oct. 30	
Clear creek			.90						Oct. 30	
Fulton ditch		91.43							Oct. 30	Added 1.96 direct seepage
South Platte river	3.55			59.54	17.94		11—1.65	61.12	Oct. 30	Below Fulton
Brantner ditch		9.57							Oct. 30	
South Platte river	24.71			34.28	30.73		7—4.39	91.85	Oct. 30	Brighton
McCann seepage ditch		4.40							Oct. 31	
Dry Creek			3.02						Oct. 31	
Lupton bottom ditch		8.21							Oct. 31	
Platteville ditch		3.55							Oct. 31	
South Platte river	49.77			62.91	38.20		8—4.78	130.05	Oct. 31	Platteville dam
Evans ditch No. 2		57.00							Oct. 31	
Beaman and Meadow Island ditches		3.00							Oct. 31	
Cook and Hewes ditch		11.60							Oct. 31	

South Platte river	6.21				77.81	28.04	8—3.50	158.09	Oct. 31	Platteville
St. Vrain creek			53.59						Nov. 1	
Western drainage ditch		10.54							Nov. 1	
Union ditch		32.44							Nov. 1	
Snyder ditch		2.53							Nov. 1	
South Platte river	50.94			42.86	36.65		9–4.07	194.74	Nov. 1	Below Union
Section ditch No. 3		1.50							Nov. 1	
Big Thompson river			23.59						Nov. 1	
Lower Latham ditch		41.60							Nov. 1	
L. L. seepage ditch		14.75							Nov. 1	
South Platte river	75.20			109.46	58.52		7½–7.80	253.26	Nov. 1	Evans lower bridge
Cache la Poudre river			68.70						Nov. 2	
South Platte river	187.77			119.07	43.87		6–7.31	297.13	Nov. 2	Kersey bridge
Sterling seepage ditch		2.50							Nov. 2	
Box Elder creek			4.54						Nov. 2	
South Platte river	222.70			220.66	32.89		8–4.11	330.02	Nov. 2	Hardin
Bijou ditch		13.32							Nov. 3	
Corona ditch		9.91							Nov. 3	
Schultz ditch		.50							Nov. 3	
South Platte river	214.44			238.17	15.47		12–1.29	345.49	Nov. 3	Head of Putnam
Putnam ditch		5.29							Nov. 3	
Weldon Valley canal		15.30							Nov. 3	
Upper Platte and Beaver ditch		44.07							Nov. 4	
South Platte river	33.93			78.00	34.82		9—3.87	462.77	Nov. 4	Fort Morgan
Lower Platte and Beaver ditch		55.84							Nov. 5	

SOUTH PLATTE SEEPAGE, 1902—Concluded.

NAME OF STREAM	Amount in River	Amount Removed	Amount Entering	Amount in River + Outtake and —Inflow in Preceding Section	Increase in Section	Decrease in Section	Increase or Decrease per mile	Total increase from Canon	Date	Remarks
South Platte river	39.42	....	....	95.26	61.33	....	11—5.58	524.10	Nov. 5	Snyder
Tetsel ditch	....	3.78	....	....	....	....	....	....	Nov. 5	
South Platte ditch	....	17.08	....	....	....	....	....	....	Nov. 6	
Pawnee ditch	....	62.26	....	....	....	....	....	....	Nov. 6	
Davis ditch	....	22.60	....	....	....	....	....	....	Nov. 6	
South Platte river	14.05	....	....	119.77	80.35	....	18—4.46	604.45	Nov. 6	Merino
Davis waste	....	....	.60	....	....	....	....	....	Nov. 6	
Snyder ditch	....	7.72	....	....	....	....	....	....	Nov. 6	
Springdale ditch	....	15.78	....	....	....	....	....	....	Nov. 6	
South Platte river	88.32	....	....	111.22	97.17	....	13½—7.07	701.62	Nov. 6	Sterling
Iliff ditch	....	10.59	....	....	....	....	....	....	Nov. 7	
South Platte river	85.00	....	....	95.59	7.27	....	11½—.06	708.89	Nov. 7	Iliff
Powell and Dillon ditch	....	2.00	....	....	....	....	....	....	Nov. 7	
Powell and Dillon ditch	....	2.50	....	....	....	....	....	....	Nov. 7	
Harmony ditch No. 1	....	4.96	....	....	....	....	....	....	Nov. 7	
Harmony ditch No. 2	....	3.06	....	....	....	....	....	....	Nov. 8	
South Platte river	102.31	....	....	114.83	29.83	....	17—1.75	738.72	Nov. 8	Crook

South Platte river	204.07	....	....	224.66	10.22	....	8½—1.20	355.71	Nov. 3	Orchard
Fort Morgan canal	....	233.13	....	....	....	....	....	....	Nov. 4	....
South Platte river	43.18	....	....	276.31	72.24	....	9—8.03	427.95	Nov. 4	Shafer's Ford
Settlers ditch	....	22.04	....	....	....	....	....	....	Nov. 8	....
Peterson ditch	....	60.62	....	....	....	....	....	....	Nov. 8	....
South Platte river	19.75	....	....	102.41	.10	....	15— .01	738.82	Nov. 8	Sedgwick
South Platte river	30.42	....	....	....	10.67	....	15— .71 229.5-3.27	749.49	Nov. 8	Julesburg

R. W. HAWLEY.

PLACES WHERE MEASUREMENTS WERE TAKEN	October and November 1899	October and November 1900	October 1901	October and November 1902
Below head of City ditch	72.93	33.96	21.22	5.04
At Littleton	133.89	74.13	32.71	18.28
At Denver	150.29	90.35	68.34	43.18
At Fulton ditch	196.90	86.96	90.06	61.12
At Brighton	274.30	160.62	141.63	91.85
At Platteville dam	324.33	194.48	225.52	130.05
At Elwood and Wheeler ditch	Old station			
At Platteville	363.09	216.70	272.30	158.09
At Union ditch	410.74	257.76	331.75	194.74
At Evans	474.59	333.80	411.14	253.26
At Kersey	....	353.43	....	297.13
At Hoover ditch	564.07	....	584.00	....
At Hardin	....	409.08	....	330.02
At Putnam ditch	624.97	412.94	593.38	345.49
At Orchard	628.22	439.54	619.31	355.71
At Shafer's ford	715.51	469.01	615.87	427.95
At Fort Morgan	722.71	512.73	684.27	462.77
At Snyder	795.34	596.50	750.14	524.10
At Merino	889.21	682.04	847.18	604.45
At Sterling	962.94	744.07	894.18	701.62
At Iliff	1,009.13	749.26	926.22	708.89
At Crook	1,078.51	772.90	938.34	738.72
At Sedgwick or above Pole creek	1,061.38	722.21	....	738.82
At Julesburg or state line	1,102.61	800.19	942.07	749.49

CALIFORNIA ROAD SPRINKLER.

MARSH NEAR GREELEY, CAUSED BY SEEPAGE.

CHAPTER VII.

DRAINAGE AND SEEPAGE INVESTIGATIONS.

Hon. A. J. McCune,
State Engineer, Denver, Colorado.

Dear Sir—I have the honor to submit herewith a progress report on my investigations of the drainage problems of Colorado, with the conclusions thus far reached.

The irrigated valleys of Colorado mark the line of agricultural progress of the state as nothing else has done in recent years. The area of cultivated land has been extended until a portion of the plain is included, the productiveness of which is a matter of surprise to the land owners themselves, and they await further development with no little interest and confidence. With the magical change which the use of water from the mountain stream has produced upon this hitherto barren and arid soil constantly before the eyes of the cultivator, it is not surprising that his entire attention has been engrossed in securing water and in applying it to such lands as he may have in his possession. Until recent years it has been thought impossible to obtain too much water or irrigate too heavily. The dry, loose and deep soil seemed ever ready to take up any excess of water that might be accidentally or purposely applied. The companies having control of irrigation canals and ditches were only concerned in supplying sufficient water to meet the demands of the purchaser of water rights, regarding leakage from the canals in the light of a loss to themselves, without any special reference to the consequences of waste which might ensue.

A new feature of the irrigation problem has gradually forced itself upon the attention of the owners of land under ditches in sections where irrigation farming has become well established. An examination of the valleys of the Poudre,

South Platte and St. Vrain rivers and Boulder creek shows thousands of acres, in the aggregate, which were once valuable by reason of their generous productiveness, but are now wet and charged with an excess of alkali, or, in case of land on lower levels, are marshes filled with rushes and aquatic grasses. When we learn from early settlers that at the time the irrigation of these lands began they were dry to a depth of from forty to sixty feet, the difference in the conditions is so great that it is well to consider whither the results of present irrigation practice will lead. The presence of saturated lands in the midst of productive fields, the swamps with pools of water surrounded by meadows available only for the meagre support of live stock, call attention to an evil which has been making insidious progress during past years and has now assumed such proportions that something should be done to arrest its inroad and restore lands thus injured to their former fertility. That these lands are valuable will be admitted by all without demonstration. They are valuable because they were once productive under irrigation and only require reclaiming in order to again yield most abundantly. They are also valuable because of their location. They belong to farmers who are provided with water rights sufficient for their irrigation. They are a dead loss to their owners, to say nothing of the unthrifty appearance which they give the country and the loss to the commonwealth of taxable property, for it is customary, and justly so, for the assessor to strike from his book all alkali and seeped lands which have become unproductive.

THE CAUSE.

The cause of this injury and what should be done to prevent its increase are questions which greatly concern the farmers of Colorado and, through them, the entire state. In the report of the State Engineer for the years 1900-1901, the part of chapter VI relating to seepage measurements, by Prof. L. G. Carpenter, has a bearing upon this question; but, as might be expected, deals with loss from supply ditches and the amount of water returned to the river, with reference to their bearing upon the subject of irrigation supply alone. I take the liberty of quoting a few deductions given in that chapter:

"The passage of water through the soil is very slow, so that it may take many years for the seepage of the outlying lands to reach the river."

"The amount of seepage is slowly but constantly increasing."

"In the Poudre river about thirty per cent. of the water applied in irrigation is returned to the river."

Investigations with reference to this subject show that there is a large loss from irrigation canals by leakage. The amount returned to the river, besides being a loss of direct supply, may have also brought about the seepage of valuable lands, before it appeared at some lower point of the river, where it may again become an available supply for further irrigation. The source of the water, with the exception of the rain which falls direct upon the land, and which need not be here considered, is the water carried by the canals, which are frequently located along the slopes or upon the plateaus. While filled and in use, they carry water to a depth of from two to four feet. The soil through which they run is frequently gravelly or sandy and ill suited for a water channel. Were it not for the silting up of these canals after they come into use, the leakage would be far greater than it is. It is a fact familiar to all that newly made irrigation canals lose a large part of their water during the first few years after construction, and further, that the old canals which are cleaned out during the winter months, or for some reason have their beds disturbed, lose water with great rapidity until the broken surface is again smoothed and covered with silt.

The following description of the manner in which lands have become seeped and rendered unfit for cultivation may be taken as representing the processes which are going on to produce these effects:

The canal, constructed in an open soil, carrying water two to four feet deep, furnishes a constant pressure upon the bottom of the canal which forces water downward with a weight of nearly half a pound per square inch for every foot of depth. The extreme porosity and great depth of soil furnishes a ready reservoir for this loss, which produces no great injury until the entire subsoil is filled with water. In case a stratum of gravel is encountered, the loss is widely distributed and may readily find its way to some lower and more level ground. If a hard-pan of clay subsoil is encountered with sufficiently close texture to arrest the downward passage of water, the water-table, as we may call the water-line of the soil, will slowly but constantly rise, and it is only a matter of time until it will reach the surface under

this constant pressure. An examination of the lower soil in the valleys before alluded to shows that there is a great difference in the texture and porosity of the soils. In some localities a stratum containing a large portion of gravel and sand is found; in others, barriers of clay not easily penetrated by water, and still others a deep loamy soil capable of storing a large quantity of water before it reaches the point of saturation.

The necessity for the drainage of these lands does not appear until the lower horizon of the soil has become saturated, thereby forming a bed upon which, when additional water is brought, it will be forced to the surface from lack of a ready outlet on a lower level. The point at which this water will appear depends largely upon the physical condition of the soil and upon the surface slope of the land, as well as the slope of the line of saturation. These several conditions are illustrated in the accompanying figures:

In Bulletin No. 33 of the State Agricultural Experiment Station it is said, as a result of several measurements made for the purpose of determining the rapidity with which water passes through the soil, that in one instance the movement was at the rate of only two and a half miles in ten years, and in another one mile per year. Whatever the facts may be in regard to the movement of seepage water under conditions such as are noted, they do not apply in any way to drainage water, for the reason that in the movement of the water through the dry soil in the process of saturation a large quantity is taken up by the soil, so that, as the water moves laterally and downward, it must fill all the voids of the soil before an advance movement takes place. When, however, the soil becomes fully saturated there is a constant communication between the water in the irrigation canal and the water along the line of the saturated plane. It has been noticed where such conditions prevail that the water in a well or pool at a considerable distance from the canal begins to rise in a short time after water is turned into the canal, since the pressure, being applied at the upper end as in case of a reservoir, forces a rise, with little intervention of time, at the lower point. Again, when the pressure is relieved the water distributes itself through the soil among portions which are less well supplied, and thus the water level begins to recede as soon as the water is shut off from the ditches. These phenomena accompanying the seepage of irrigated lands have been observed, and lead to the reasonable conclusion that the rise of water in the lower

portions of land where seepage occurs is produced by the head of water in the ditch, and that the reason why water appears in one locality and not in another may be explained by the difference in the physical condition of the soil at varying levels. Thus it may appear that water which passes through the bottom of the ditch may not have a direct lateral passage through the soil until it reaches some porous or gravelly stratum, or possibly of firm clay, where, finding relief in some direction, it is forced laterally and appears at some lower level, possibly a mile or two from the head. With such variable physical conditions, it will not be difficult to understand the apparently unaccountable appearance of seep-water at a considerable distance from the source.

The opinion has been advanced by some that the entire source of water which seeps irrigated lands is the excessive supply sometimes used in farm irrigation. That there is a great waste in the use of water in some localities and that it has something to do in some instances with the degree of saturation can not be denied. But from the causes before explained, it will readily be understood that this can play but a small part in producing the evil which we are considering. The water used in irrigation is applied upon the surface at a distance from the main canal and must saturate all of the soil downwards before it reaches the lower levels. Where saturation already exists to some extent, over-irrigation may aggravate the evil.

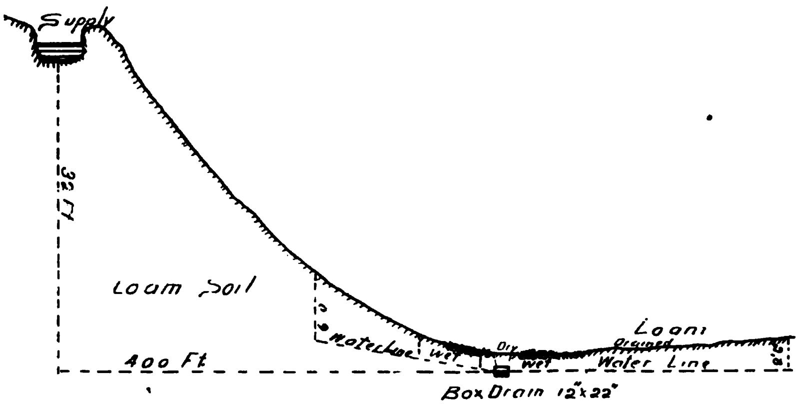
ALKALI CONDITIONS.

The wet and swampy condition of soil produced by seepage is not the only evil to be deplored. Arid lands contain a large amount of soluble salts to which they, in a large measure, owe their fertility. These originated in the rocks from which the soils were formed and are distributed through their entire depth. When in solution they furnish that concentrated plant food which gives these arid soils their reputation for great fertility. The capillary power of most of these soils is great, owing to the mechanical fineness of particles and their peculiar chemical composition. It is not uncommon to observe that capillary water is raised three or four feet upward through the soil. When water is applied to such soils as are now under consideration, the salts are dissolved and as the water is brought to the surface by gravity or capillarity, it is evaporated by solar heat and the salts are deposited upon the surface. As this process continues each successive

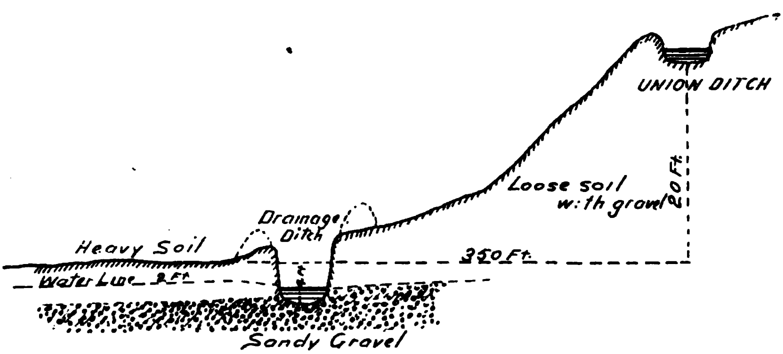
evaporation adds to the quantity of solid salts until the surface becomes so permeated by them that crops can not be grown. These salts are mainly sodium chloride, sodium sulphate and sodium carbonate, the latter being much more destructive to vegetation than others. Owing to these facts, seeped land is commonly spoken of as alkali land, for while excessive moisture will prevent the growing of useful crops, the accumulation of alkali, especially the sodium carbonate, is found to be the more formidable evil. For this reason land which has once become seeped and the surface filled with alkali, is barren and will remain so until the water-table can be reduced to the proper point and the alkali dissolved and more evenly distributed through the soil. These facts are well known to the owners of irrigated land, and the losses from seepage are deplored. What is wanted is an effective cure for this growing evil. The ditches in some cases could be improved, especially where they pass through permeable material, but a certain amount of seepage seems unavoidable and drainage of some sort adapted to the needs of individual cases appears to be, and undoubtedly is, the only feasible remedy open to the land owners.

THE PROPER DEPTH FOR DRAINAGE.

The first consideration in the drainage of these lands is to determine the depth to which the drains should be made, or in other words, the distance from the surface to which the water-table or line of saturation should be reduced. Practice along this line has proven that shallow drainage is not sufficient and, in fact, useless. The great capillary power of the soil is such that water is brought to the surface of the ground through a depth of three or sometimes four feet of soil. From recent investigations made by the Bureau of Soils it is shown that a solution of sodium carbonate rises in the soil higher than solutions of other salts, and higher than distilled water in the ratio of forty to thirty-six. This may explain the fact so often observed, that black alkali, known to the chemist as sodium carbonate, appears on land even though the water is found at some distance from the surface. At all events, it is sufficiently well demonstrated that the drain should be so located that it will keep the water down at least four feet from the surface. This will necessitate the flow line of drains being located five feet below the surface and even greater depth would in many cases be more efficient. It may be remarked,



SECTION ON WETZLER FARM NEAR FORT COLLINS.



SECTION SHOWING WATER LINE NEAR DRAINAGE DITCH ON GODFREY BOTTOM.

also, that the capillary action of the soil is increased by the application of water upon the surface, which, percolating downward to the water-table, establishes a communication between the surface and the subsoil water, which, for the time being, may accelerate the capillary movement of the water toward the surface. The universal failure of drains three feet deep in the deeper and lighter soils of irrigated lands, and the success of those five feet deep, practically establishes the latter as the minimum in the treatment of seeped soils. Some bottom lands, however, containing more clay and possessing less capillarity are improved by more shallow drainage.

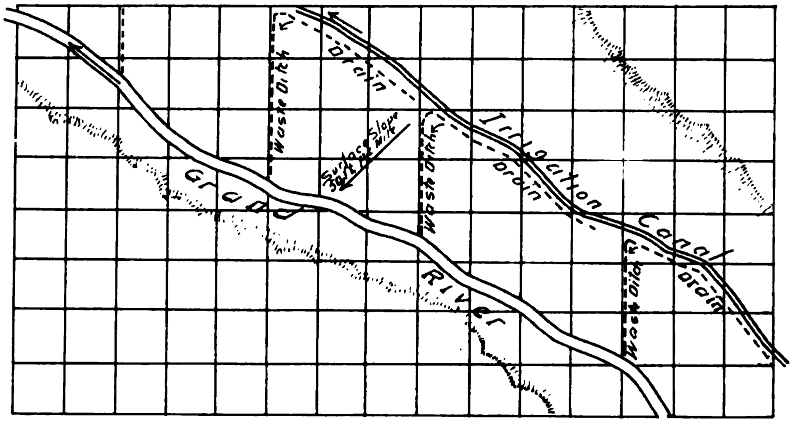
PRESENT PRACTICE.

Through the assistance and courtesy offered me by your office I was enabled during the present year to examine several tracts of land on which drainage has been practiced with greater or less success. These examples are very valuable by way of indicating what should be done in the different classes of soils. I take the privilege of referring to these instances and of drawing such inferences as I am able, with a view of placing the facts directly before your office and those who are particularly interested in the reclamation of seeped lands. The use of the open ditch for cutting off seepage or percolation of water from irrigation canals is the first suggestion that presents itself. An instance of this method is found on the Union ditch, south of the town of Greeley, by means of which a large tract of South Platte bottom land, called the Godfrey bottom, has been reclaimed with a fair degree of success. I am told that previous to the construction of this ditch, the entire bottom was swampy and unfit for cultivation. The irrigation ditch extends along the edge of the slope thirty feet or more higher than the bottom land. The ditch, as shown, is constructed at the foot of this slope and parallel with the course of the ditch and is excavated four or five feet to a layer of gravel which apparently underlies the entire bottom land. This ditch was constructed by a dredge at a considerable expense and furnishes a constant supply of water, which is appropriated farther down the stream for irrigation purposes and as such has become valuable. From borings made at a point shown in the accompanying sketch, it appears that the water is not farther than two feet from the surface. The soil, however, is heavy, black and loamy and much less permeable to water than the upland soil, and for this reason excellent crops are produced with the water line

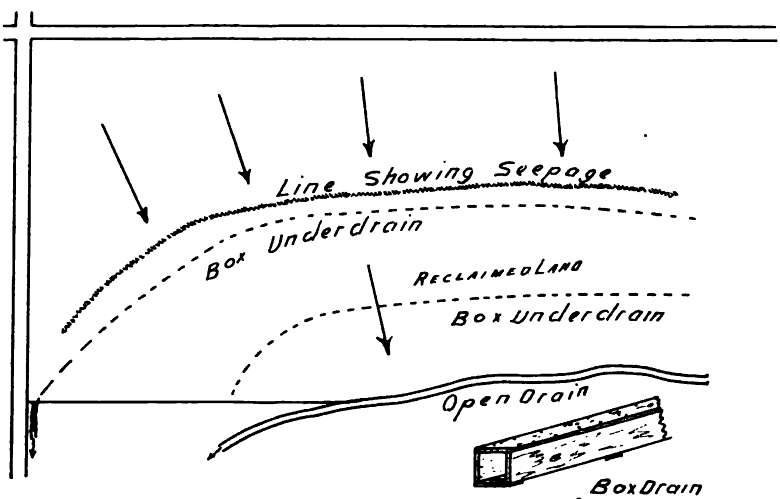
eighteen inches or two feet from the surface of the ground. This example shows one condition of soil which is found in this valley and indicates how effectual drainage may be accomplished. It is evident that water from the irrigating ditch sinks directly downward until it reaches the stratum of open gravel; where it approaches the surface at some lower level, the head of the water in the ditch at once forces it upward or latterly to the surface. An intercepting ditch constructed through this gravel breaks the force of the head and conducts the intercepted water to an outlet.

Another instance of drainage upon this principle is found on what is commonly spoken of as the Wetzler farm, near Fort Collins. In this case a box-drain is laid at the foot of the slope, parallel with the course of the No. 2 canal. This box-drain is about twelve by twenty-two inches in section and about three-quarters of a mile long. It effectually cuts off the water from 200 acres of land upon which wheat, oats and other crops are successfully grown. The insufficiency of a shallow drain is shown in this instance at a point near the outlet, where it is placed only two feet deep. Where it was laid four or five feet deep, the drainage is effectual. This again shows the effectiveness of a cut-off or intercepting drain at the upper edge of a flat which had become saturated by seepage direct from the canal, demonstrating quite conclusively that it is necessary to cut off the head of water on a line parallel with a supply canal, if the land below is to be effectively reclaimed.

An interesting example of two methods of drainage is found west of Greeley, on the farms owned by Mr. F. H. Badger and Mr. Neff. Their land was injured by seepage from the No. 2 canal. Mr. Badger has drained a twenty-acre field direct by the use of drain-tiles, placed in three lines through the field, approximately four feet deep. He is succeeding in draining the land quite effectively, as the crop of sugar beets grown this year seems to prove. Mr. Neff, who owns land directly adjoining this field, on the west, has constructed a cut-off drainage ditch parallel with and between the No. 2 ditch and his land, and made an outlet for the same down the road to the supply ditch. He also has beets upon his land, which are thriving and promise a good crop. The latter has apparently drained his land by the intercepting ditch, as well as the former has by a system of drains through the land directly affected by seepage. It should be considered also, that Mr. Neff's drain is of service to Mr. Badger's land, by cutting off some water which would otherwise reach it.



DRAINAGE PLAN PROPOSED FOR GRAND VALLEY.



GENERAL PLAN OF CUT OFF UNDER DRAINS USED BY J. HETZEL ON HIS FARM NORTH OF LONGMONT.

Some interesting work along this line has been done by Mr. Albert Igo, on his farm west of Greeley. He has sunk a series of small wells several feet into the gravel in the land which was saturated and connected these wells with drains at convenient depths with an outlet ditch. Water rises from the gravel in these wells to the level of the outlet drain and, by gravity, passes away. These wells being sunk into the gravel, which is filed with water, simply relieves the pressure of the water which it derives from the supply ditch, and permits it to pass away without being forced to the surface through the soil. It is quite evident that an intercepting ditch cut into the gravel, provided with a suitable outlet, would accomplish the same result. But, of course, the wells are more easily constructed and are cheaper, and if they accomplish the purpose, are certainly commendable. This system of drainage is applicable to lands having open gravel strata in which the water collects and is accomplished by the sinking of wells at points where drainage is required, and the construction of an outlet for the same to some more distant point.

Some considerable progress has been made in the drainage of lands north of Longmont and in the vicinity of Highland lake. Through the courtesy of Mr. L. C. Mead, my attention was called to several examples of successful drainage in that vicinity which have been accomplished upon the same lines as previously described. In that locality there is no gravel subsoil; on the contrary, a rather heavy clay is found at a depth of four or five feet. Some drains constructed by Mr. J. Hetzel demonstrated the efficiency of the work in that class of soils. He laid box-drains along the upper edge of the field which began to show seepage. The irrigation ditch from which this water comes is some distance from the saturated land, but lies twenty feet or more higher. His plan, briefly stated, is to lay the drain on a contour line along the upper edge of the seeped portion, giving as much fall to it as may be necessary to insure a flow, and extend the drain to some outlet point. If this fails to provide all the drainage necessary, he constructs a similar drain down the slope parallel to the first. Mr. Hall, in the same neighborhood, has also marked results from the construction of one drain on the upper side of his farm, between it and the supply ditch. His land is much more level than that first described, but the result is fully as satisfactory. In the experience of each of these gentlemen, they found it necessary to construct the drain where seepage first appeared. If that failed to reclaim the entire

tract, the seepage which appeared later would indicate where the next one should be placed. These examples of actual experience are of great value to the farmers of Colorado, indicating a few instances where seeped lands have been reclaimed. In most cases there has been but little difficulty in removing the alkali which had filled the soil during irrigation and cultivation. In some cases the alkali was so slight that a full crop was produced the year following drainage. In every instance the facts so far obtained show that where drains were placed at the proper depths, and in such locations as to intercept seepage water before it reached the lower levels, the measure of success attained is sufficient to merit attention.

TWO SYSTEMS OF DRAINAGE.

In considering the details of land drainage which are to be adapted to the needs of such land as we have under consideration, it may be well to consider briefly the two systems of locating drains which may be employed. The first consists of locating drains across the general slope of the land and extending them to a point where they may have a common outlet. The second consists in locating drains up and down the slope, extending them in a line of the greatest surface slope, until an outlet may be obtained. The latter is a system which has been employed where water to be removed comes from rainfall alone at irregular times and in variable quantities. The water under such conditions falls upon the surface of the land which is to be drained, sinks directly into the soil or passes slowly over the surface in the line of the greatest descent, seeking, by gravity, some point where it may run off freely. It readily passes laterally or downward along the line of least resistance. In this way the land becomes relieved of water, if properly underdrained. The alternate drying and saturation of the soil gives it a varying capacity for any surplus moisture. Under such circumstances the first mentioned system of drain location has not been as successful as the latter. The tendency of the water being to pass down the slope and across the drain, leaving the land near the drain unaffected.

It will be observed that in the drainage of seeped lands so far described, the former method has been usually practiced. The conditions under which land becomes saturated by rainfall and seepage are radically different. In seeped lands, the soil water is under a constant head, being continually forced up into the soil, the degree of pressure and

its effect depending upon the height of the water surface and the porosity of the overlying soil. As long as there is water in the ditches, the pressure is constant, but as soon as the water is turned off, it has been observed that the soil water begins to recede. In the case of rainfall, the water to be drained away falls directly upon the land; in the case of seepage, the supply is possibly far distant and the pressure and flow are continuous. In this case the system of cross-drains serves to cut off the supply, which to be effective, should pass every consecutive point between the source of supply and the land affected. It may be said with truth, that such a drain will not intercept all of the water. But in the case of irrigated soils, it should be understood that the soil being deep and porous will care for a certain amount of water without producing an injury to the land. It may also be of advantage in affording sub-irrigation. It is only in case of saturation to such a degree that the water line comes too near the surface that injury is effected. It has been observed that where drains have been laid up and down the slopes for the purpose of draining seeped lands, that the pressure frequently forces water to the surface between the drains, or even directly above them, so that drains located upon this system, must be expensively close together and even then may fail to effectively accomplish the desired purpose. There seems to be no question that for the prevention of seepage, the cross-drain system is the more efficient and much cheaper. For the purpose of locating the drains most effectively, the line of land which first shows saturation should be accurately traced and a cross-drain should be made five or six feet deep, at or near this line. If gravel can be reached at this depth, there will be but little risk of failure. If only soil is found, it may be necessary to construct other drains parallel to the first, especially if the surface slope is quite heavy. Some skill and close observation in determining locations will be required in order to bring about the best effect. The watercourses in the soil and the necessity for drainage work can be only learned when water begins to appear in the land. Surface indications are worth but little. When, however, saturation shows, no time should be lost in beginning drainage operations, for the evil will increase rather than diminish.

KINDS OF DRAINS.

The kind of drains which will be most serviceable will depend largely upon the magnitude of the work undertaken,

and upon the character of the soil. For the reclaiming of large tracts, the open ditch is the only drain which may be used. The quantity of the water seeping through the supply ditches varies so greatly at different points, that ample provision must be made for the drainage even at the expense of making the drains, at some points, unduly large. As has been previously noted, depth is an important element in the intercepting drain and in order to secure it and maintain the proper depth in the loose soils with which we have to deal, it will be necessary to make the ditch not less than three or four feet wide on the bottom. There is an objection to open ditches for this purpose which can not be overcome. The quantity of water is not great, but constant, thereby encouraging the growth of vegetation, which, with the lodgment of loose earth and trash, obstruct the flow. Nothing but timely care and cleaning out under these circumstances will keep it in proper condition for the office it is intended to fill. Such ditches constructed parallel to the course of a supply canal will develop a very considerable amount of water, which in the course of a few miles, may become available and valuable for irrigation purposes, and may be appropriated under the provisions of the state irrigation law. A large ditch of this kind may not in all cases intercept all injurious water and may possibly require supplementing by smaller or individual farm drains. Where a large tract such as has been described is to be drained, involving the land of a number of different owners, some drainage district law providing for co-operation of land owners should be enacted. It may be necessary for two or more farmers to join in the construction of a common drain or for securing an outlet for field or farm drains. In each case they should, in equity, bear the expense of such work in proportion to the benefits which they receive. The disposal of the water developed by drainage work may give rise to some complications under the irrigation law, but they can probably be adjusted without material difficulty. Without a proper state drainage law, however, no drainage can be accomplished, except such as may be carried out by individual farmers upon their own land. This matter should receive careful and prompt attention in view of the necessity in some quarters for at once beginning a comprehensive system of drainage.

Covered drains should be used whenever the area of the tract does not require drains of greater capacity than may be profitably constructed in this way. The one most commonly used is the box-drain, which is constructed of

boards or planks. The smaller ones have no bottom except cross pieces which are used to strengthen and hold the box together. These are made in lengths of from twelve to sixteen feet and laid with the open bottom down and joined at the ends. The large drains are made of planks two inches thick, while the smaller ones are made of one inch boards. Considerable difficulty in the construction of these drains is found by reason of the caving in of the ditch before the box can be put in place.

Drain tiles and sewer pipes have also been used with some success. Difficulty has been experienced in securing a sufficiently stable bottom upon which to place the pipes and also maintaining them afterwards in the proper position. This may be largely avoided by digging the ditches at a time when the water level is below the grade line of the drain. It seems to be the common practice to wait until the soil is full of water, then dig as deep as practicable, grading by the water which flows from the soil. The loose character of the soil and the presence of quicksand make it extremely difficult to secure a proper bottom, so that the board or plank drains laid in long sections have been found easier to maintain in a secure position. The most of this trouble can be avoided by digging the ditch during the dry season of the year, that is, during the winter when there is no water in the irrigation ditches. The drain may be laid upon a proper grade, such as may be given by a survey with much greater dispatch and more cheaply. The course and depth of the drain, however, should be determined upon while there is water in the ground. If drains are laid when the soil is dry, a firm bed will usually be found and the drains made of either plank or pipe will remain in proper position. Of course, there may be pockets of quicksand or exceptional cases where planks may be required, but the laying of the drains during the dry season will very much simplify and expedite the work.

The prices of tile drains compared with board drains are quite high, and for this reason the board drains are more frequently used. They are laid in the Longmont region five feet deep at a cost of from 85 cents to $1.00 per rod. Drains of this description are made of two boards, six inches wide and capped with one board eight inches and stiffened by cross pieces at the bottom, making a drain well adapted to field drainage where there is a light grade. Should the grade be heavy the drains with no bottoms are not suitable, for the reason that the water washes away the soil very rapidly

and they will sink out of place and finally collapse. Instances of such drains laid down the slope through sandy soil can be referred to.

With reference to the tile-drains it may be said that they are more suitable and should be used if they can be secured at a reasonable price. If made of proper material and hard-burned, they are durable and efficient. The American Beet Sugar Co., of Rocky Ford, has begun the tiling of their wet lands, having during the present year laid over 23,000 feet of drain-tile. The company has experienced the difficulties of laying the drains before mentioned. The action of the drains upon the land, however, is quite satisfactory. With reference to open ditches for drainage, Mr. Winterhalter, agricultural superintendent for the company, says: "Open drains have only been resorted to to take off the tile-water into the river or to the factory sewer ditch. Generally speaking, they are not successful in this country, owing to the growth of noxious weeds, which obstruct the free flow of water, and also because they fill up quickly with Russian thistles and tumble weeds, which are carried for miles through the country by spring storms." If the survey before mentioned is made so that the pipes can be laid in a dry soil instead of a wet one, there will be no difficulty, neither will the pipes fill with soil or sand if they be properly joined. Pipes two feet in length are preferable to the short ones and a covering of tarred paper placed over the joints at the time they are laid will prevent sand from entering the drain. They should have a uniform grade not less than two inches per 100 feet, if it is possible to obtain it, and the earth should be filled very compactly about and above to the full depth of the ditch. It is essential in the covered drains that the ditches be well filled and more than ordinary care be taken in compacting the soil which has been excavated, for the reason that when irrigation water is applied, there is danger of it flowing into the ditch and through the drain. The mistake may be easily made of making these drains too small. The amount of water which they are expected to carry is variable and uncertain. One portion of the field may furnish double the water that another portion of equal length will furnish, because of the difference in the porosity of the subsoil. In fact, a drain in order to cut off seepage from a particular place, may extend for a considerable distance through a portion of land requiring no drainage whatever. In such cases the drain may lose a portion of its water in the soil before it arrives at the final outlet. All of these conditions are so variable that it is difficult to antici-

pate all of them and the drainer of seeped lands will find in every new field he undertakes a work requiring special examination. One failure of pipe-drains which may be noted, is the insufficiency of size which has been used. For accomplishing the best results, a drain should never run full of water. There should be a space of air at the top of the flowing water which will aid in destroying the capillary connection between water and soil. If the drain is filled with water, of course the soil is saturated to the crown of the drain and begins at once to conduct capillary water to the surface, which a space of air would help to check. A size no smaller than six inches in diameter should be used for cut-off drains of minimum length and ordinarily eight-inch tile should be used. With reference to the durability of the board-drains, it is urged by their users that lumber kept completely saturated is durable. There are instances in which wooden drains have been operating ten years or more without failure. It can not be expected, however, that such drains will be permanent. They may pass through soil which at times may be sufficiently dry to produce decay, and it is only a matter of time when they will fail and require renewing. It is to be hoped that a more lasting material may soon be available to all of those who wish to construct underdrains.

REMOVING ALKALI.

The alkali question has been touched upon only incidentally. Its prevention rather than its remedy has been sought for so far in the discussion of the drainage problem. If the matter of reclamation were taken up when the evil first appeared, but little if any delay would be occasioned in restoring the land to its original productiveness. After it has been subjected to saturation for some years and the salts of the soil have become concentrated upon the surface, especially the sodium carbonate or black alkali, proper cultivation, together with judicious irrigation will be required. After the water has been once cut off, the soil soon dries out and judicious irrigation dissolves the surface alkali and carries it back into the soil, where by successive irrigation, by winter rains and the growing of crops which are tolerant of alkali, it becomes distributed through the soil without being washed away and lost. Should the soil become so strongly permeated with alkali that profuse washing by irrigation for the purpose of carrying it entirely out of the soil is required, a system of under-drains would be necessary to provide an exit for the water which is applied for that object. In any

case a cut-off drain would be necessary to relieve the hydraulic pressure and permit the free action of the drains in removing alkali water. Such a system, if constructed, should be laid down the slope as is done for the drainage of surplus rainfall. As far as I have observed, the alkali which has been brought to the surface by seepage has been neutralized and carried away by ordinary methods of management, the soil, after the seepage has been cut off, taking care of the water which is applied in ordinary treatment of the land.

THE GRAND VALLEY.

On the western slope of the state are found some of the most fertile valleys within its borders. The portion of the valley of the Grand river between the towns of Grand Junction and Fruita contains apple, peach and prune orchards, which produce fruit of superior quality and in greater abundance than any other part of the state. The shipments of fruit from Grand Junction alone run from 300 to 500 cars per year. Other crops, such as potatoes and sugar beets, can not be surpassed either in quality of product or in the abundance of yield. On either side of the river cliffs rise one mile high, giving this rich valley that beneficent protection which insures regular and bountiful crops.

Water for irrigation is furnished by a ditch from the Grand river. With its branches it is over seventy miles long. It winds down the valley in that irregular manner which is a characteristic of these artificial channels. The slope from the canal to the river is fifty feet per mile. The soil, though fertile, is much different from that on the eastern slope. It is heavier and not so tractable when first broken up, but when once subdued, irrigated and cultivated, produces with gratifying luxuriance. This valley gives promise of becoming one of the greatest fruit producing regions of the West. The apple, peach and prune seem to be at home in the soil, to say nothing of other fruits and cereal crops. An abundance of water is available which is used with great prodigality. The soil is partially of shale origin, that formation in some localities being within two and one-half to three feet from the surface, though it is usually found from twenty to forty feet from the surface.

This brief description is given in this connection for the reason that, like portions of the valleys on the eastern slope, some of the farms here are suffering from the results of seepage and over-irrigation. The salts brought to the surface by

DRAINAGE DITCH AND LAND PROTECTED FROM SEEPAGE, POUDRE VALLEY.

WASTE DITCH IN GRAND VALLEY,
WHICH MAY BE USED FOR A DRAINAGE OUTLET, TWELVE FEET DEEP.

the evaporation of soil water are more largely sodium chloride and sodium sulphate, the black alkali or sodium carbonate showing less abundantly than in the valleys previously described. The soil retains water with considerable tenacity, so that it may be said to be close when compared with the irrigated soils on the eastern slope. Strange as it may seem, portions of orchards are already ruined and present the appearance shown in Fig. 7. A bed of shale, through which the water percolates, underlies this once productive peach orchard. The alkalai and spots of saturated soil upon the surface mutely indicate the cause of the ruin which has been wrought, while the adjoining orchards, which are not yet seeped, emphasize the marked difference between two conditions of soil which is met with elsewhere in this valley. This orchard died from an excess of water—that constant under-supply which knows no abatement or let-up as long as water flows through the canal. Other lands between the towns of Grand Junction and Fruita bear abundant evidence of the growing inroad of seepage devastation. The patchy fields and orchards, the abundant and increasing whiteness of the soil in certain localities are witnesses to the fact that something ought to be done to head off the evil which is destined to grow more formidable as the years go by. In my judgment it can be done, and the sooner some practical plan can be carried into effect, the greater will be the saving of property.

The plan is simple and is this: Excavate a series of ditches below and parallel with the supply canal and give each an outlet to the river through waste ditches, which are required by the canal, some of which already exist. The plan is outlined in principle only in Fig. 8. The cut-off ditch should be from six to eight feet deep, and located below the canal, along a line most favorable for intercepting the seepage. The waste, or receiving ditches, should extend to the river along land lines where they will be the least objectionable and will accomplish the most good. The fall of the land is such that there will be no difficulty in securing sufficient grade for self-maintenance. The waste ditches will require checks and other precautionary measures to prevent too great erosion by waste flood water, which must be provided for.

A simple system of this kind will thoroughly check the inroad of seepage and make every acre on the lower side of the canal equally free from seep water. Here again arises the need of a state drainage law. This is a work in which all land owners must co-operate under the provisions of a law by which the expenses of the work can be equitably adjusted,

legally collected and applied properly to the laying out, construction and maintenance of the work. This evil is just beginning here. The shale subsoil, or, more properly, base of the soil, sometimes changes its structure after irrigation begins, producing favorable drainage conditions, but the appearance of wet lands along various points of the entire length of the canal, especially noticeable between Grand Junction and Fruita suggest the wisdom of giving attention to this matter at once. The area may be taken up in divisions, the tract lying between two succeeding outlet-drains which extend to the river being treated as a separate district in construction and maintenance. One of the several steam excavating machines may be used upon this work.

With such a system of intercepting drains, any detail or individual drainage which might be found necessary later can be done. However, with the drainage ditches properly located and constructed, few cases will arise where further ditching will be necessary unless it be some of those lands which lie farther toward the river. This valuable fruit belt will then be reasonably secure from the dangers of seepage. The uniformity and certainty of the crops will then attract growers to such an extent that all of the unoccupied land will soon be brought under a high state of cultivation. No other improvement which can now be proposed for this valley will be of such material and lasting benefit as the simple and efficient drainage herein suggested.

The investigations thus far made cover but a small part of the state. The details of the work done can not be given in this brief report, but the results of the examinations have been pretty fully outlined. Every additional field which I have had the privilege of visiting and looking over, even in a superficial manner, only emphasizes the necessity for immediate attention on the part of land owners, to the seepage question. While efforts are made to obtain greater supplies of water and to enlarge the area of cultivated lands, it is unwise for the owners of lands already under irrigation to allow portions of their domain to become and remain worthless because of lack of drainage. The drainage of irrigated lands is destined to become a part of agricultural operations which will follow in the wake of the development of arid regions, and should receive the attention of both ditch builders and land owners. Already the value of seepage water for irrigation purposes is appreciated and is being appropriated at various points where it can be readily collected. If the large areas of wet land were reclaimed, the resulting drain-

age water would be large in quantity and of great value. The control of its use should be vested in some authority of the state, and the drainage itself, when the co-operation of land owners is required, should be performed in accordance with the provisions of a simple and efficient drainage law, which should be enacted at the coming session of the legislature. With this end in view, it would be wise for your office to urge the necessity of such measures.

Respectfully,

C. G. ELLIOTT,

Agent and Expert, Irrigation Investigations, Office of Experiment Stations, U. S. Dept. of Agr.

CHAPTER VIII.

THE MEASUREMENT OF WATER.

A. L. FELLOWS.

INTRODUCTION.

The irrigation interests of Colorado have assumed such importance that officers connected in any way with irrigation are constantly in receipt of applications for information concerning the distribution and use of water. On this account it has been thought advisable that a bulletin be published which should set forth, as briefly and yet as clearly as possible, some of the most improved methods of measuring water used for irrigation purposes, comprising a few of the most essential tables for calculating the discharge of water in open channels, over various forms of weirs, and through some of the more ordinary styles of orifices and pipes.

It is intended that this bulletin shall cover simply the more elementary principles of hydraulic measurements, with the hope that it may be of service to the average irrigator rather than to the expert hydraulic engineer. At the same time, it is believed that the information contained herein may be of value to water commissioners and superintendents, and to others whose duty it becomes to measure water, and also to young engineers and surveyors, more especially by indicating to them the authorities upon the subject of hydraulics whose works have been of the greatest use in the preparation of this pamphlet. No pretense is made that this is more than a brief compilation from the works of Neville, Bazin, Trautwine, Fanning, Carpenter, Hall and others, to all of whom it is desired that due credit be given, together with some additional memoranda made by the writer during the course of a number of experiments. I am especially

indebted to Professor L. G. Carpenter, of the State Agricultural College at Fort Collins, for his kind permission to make use of the tables contained in his admirable Bulletin No. 27, upon "The Measurement and Division of Water." I have made use also of the bulletins and reports of the United States Geological Survey, and of the suggestions of Mr. F. H. Newell, chief hydrographer, to whom especial thanks are due.

To these gentlemen, and to all other sources from which the information herein contained is derived, I am indebted for the greater part of the contents of this bulletin.

DEFINITIONS.

As it will be necessary to use some terms more or less technical, it is desirable that enough definitions be given to make clear any expressions containing them.

The first to be considered are those used in measuring water. The unit which the law of Colorado requires the State Engineer to adopt, and which is preferred by all engineers and by all who are thoroughly familiar with the term, is the "cubic foot per second of time," or "second foot," for flowing water, and the "cubic foot" for measurement of volume. Section 2467 of the irrigation laws of Colorado is as follows:

"Unit of Measurement. The State Engineer shall use in all his calculations, measurements, records and reports, the cubic foot per second as the unit of measurement of flowing water, and the cubic foot as the unit of measurement of volume." L. '89, 374; section 10.

The same units have been adopted by the engineers of the other irrigating states.

By "cubic foot per second" is meant sufficient water flowing through any kind of a conduit to exactly fill a receptacle holding one cubic foot, or 1,728 cubic inches, once in each second. It may be defined in a number of different ways, also. Mr. Newell defines it as the amount carried in a flume with a square cross section one foot deep, one foot wide, and flowing with an average velocity of one foot per second. A moment's thought will convince the reader that the various definitions are but different ways of expressing the same amount. The idea intended to be conveyed may be clearer to some if it be remembered that a cubic foot of water is equal to seven and one-half gallons, and that we may therefore say a cubic foot of water per second, or a

second foot, is simply a stream which will furnish seven and one-half gallons of water every second. It will readily be seen that a knowledge of the depth and width of the stream is not sufficient for the determination of its discharge, but that the volume is dependent upon the three factors of depth, breadth and velocity per second; or, more simply, upon the area and average velocity per second, the three, measured in feet, when multiplied together, giving the amount discharged in cubic feet per second. For example, if a stream has an average depth of two feet, and an average width of four feet, and flows throughout the cross section with an average rate of three feet each second, the quantity of water flowing would be $2 \times 4 \times 3 = 24$ "cubic feet per second," or "second feet." If, however, the stream is more sluggish, the velocity being one-half of one foot per second, the discharge would be $2 \times 4 \times \frac{1}{2} = 4$ "second feet." Again, if the average velocity is one foot per second, the number of second feet will be equal to the cross section of the ditch or conduit. In this case we have $2 \times 4 \times 1 = 8$ second feet. It will thus be seen that streams which look about the same may give widely varying discharges. The formula for discharge measured in cubic feet per second is, then,

$$D = A \times V$$

In this formula "D" equals the discharge of the stream in cubic feet per second, "A" equals the area of a vertical section of the stream perpendicular to the direction of its current, in square feet, or the product of the average depth and width of such section, and "V" equals the average velocity of the water in feet for a single second of time.

The term "a cubic foot" is, of course, an exact term, capable of but one meaning, namely, a cubic foot equal to 1,728 cubic inches; it is also equal to almost exactly $7\frac{1}{2}$ gallons, weighing about 62.4 pounds at average temperatures. Table 1, on page 181, gives a number of equivalents for the cubic foot and other units of measurement, that will be found convenient for reference.

In calculating the volume of water in great quantities, as in large reservoirs, where the number of cubic feet might run up into the millions, another term dependent upon the cubic foot is sometimes used, which is the "acre foot." This simply means enough water to cover an acre uniformly with water one foot deep, and is, of course, equal to the area of one acre, or 43,560 square feet, multiplied by one foot depth, giving 43,560 cubic feet. For example, a reservoir contain-

ing 4,356,000,000 "cubic feet" of water would contain 100,000 "acre feet." The term "acre foot" has the additional advantage that it gives an approximate idea as to how much land can be irrigated from a reservoir when its capacity, or the amount of water which it contains, is known, as it may be estimated that it will take about two acre feet to provide water for one acre of land for the irrigation season.

TABLE 1.

1 cubic foot of water weighs about 62.4 pounds.

1 cubic foot per second	= 7.4805 (about 7½) gallons per second.
	= 38.4 Colorado statutory inches.
	= 50 California statutory inches.
	= 1 acre foot in 12 hours, 6 minutes.
	= 86,400 cubic feet in 24 hours, nearly 2 acre feet.
1 acre foot	= an acre covered with water 1 foot deep.
	= 43,560 cubic feet.
	= 325,851 gallons.

Another term in common use is the "inch." There are several kinds of inches, but the quantity most commonly intended when the term is used in this state is the Colorado "statutory inch," the law defining it being as follows:

"Water sold by the inch by any individual or corporation shall be measured as follows, to wit:

"Every inch shall be considered equal to an inch square orifice under a five-inch pressure, and a five-inch pressure shall be from the top of the orifice of the box put into the banks of the ditch, to the surface of water; said boxes, or any slot or aperture through which such water may be measured, shall in all cases be six inches perpendicular, inside measurement, except boxes delivering less than twelve inches, which may be square, with or without slides; all slides for the same shall move horizontally and not otherwise, and said box put into the banks of ditch shall have a descending grade from the water in ditch of not less than one-eighth of an inch to the foot." (General Statutes of 1883, page 1015, section 3472.)

The term is often confounded with other kinds of inches, however. It is not uncommon for it to be used referring to

a square inch of water flowing over a weir or in open channels, a stream having a cross section of one square foot being spoken of as 144 "inches," without reference to the velocity, and hence without reference to the quantity. Again, it is sometimes confused with the "miner's inch," which is the flow through an inch orifice with only a four-inch pressure. When inches are spoken of, therefore, the speaker may have in mind such quantities of water as may be discharged from an orifice or through a conduit having a cross section of a given number of square inches, quantities varying with the velocities, dependent upon any number of different conditions; 144 of them to the second foot, for example, when the average velocity is one foot per second, or he may mean California statutory inches, of which it takes fifty, more or less, to make a second foot; or Colorado statutory inches, of which there are 38.4, more or less, to the second foot. It will be observed that in each case the words "more or less" are used; this is necessary because the "inch" of water, even at its best, is but a variable quantity. The shape and nature of the orifice, the velocity of approach, or of the current past the orifice; the angle at which the orifice faces the stream, and the width of the opening, are all factors that have most intimate bearing upon the discharge. In the case of the Colorado statute inch, for example, the ratio of the discharge to the width of the orifice is by no means constant. Let us suppose that we have two gates delivering water from the same ditch, both of them complying exactly with the requirements of the statute, but one having an orifice three inches wide, and the other having one six inches wide, each being six inches high and with a five-inch pressure from "the top of the orifice to the surface of the water;" the first would give a discharge of 18, and the second of 36 "statutory inches," but as a matter of fact the second would be giving a good deal more than twice as much water as the first, for the reason that the average velocity of the water through the second would be considerably more than that through the first. This branch of the subject will be discussed more fully later.

It is evident, therefore, that the cubic foot is the only exact term used in measuring water in common use. As stated previously, this may perhaps be better understood by some if we substitute for the term "cubic foot" the words "7½ gallons," its equivalent. We should then say 7½ gallons per second, or 15 gallons per second for two cubic feet per second of time. Hereafter, therefore, we shall use the term "cubic

feet per second," or "second feet," as an abbreviation of the same, when discussing measurements or quantities of water.

A number of other more or less technical terms will be met with as we proceed, the definitions of which will be given as they may be required.

In considering the flow of water we shall take up the various phases in the following order:

First. Discharge in open channels.

Second. Discharge over weirs.

Third. Discharge through orifices.

Fourth. Discharge through pipes.

DISCHARGE IN OPEN CHANNELS.

It is evident that water flowing in open channels will be in the most nearly perfect condition for accurate measurement when it is flowing freely in a well-constructed flume, the floor of which is carefully laid to grade and is free from sand, gravel or other obstacles tending to impede the flow of the water, and whose sides are likewise free from all obstructions. Moreover, in order that the conditions for measurement shall be as nearly perfect as possible, the flume should be straight and the swiftest current should be about in the center, while no eddies or backsets should exist at the point of measurement. These are the conditions sought for when careful ratings or gaging are to be made, and it is with these in view that rating flumes should be constructed. In this connection a few conditions to be fulfilled in the placing of a rating flume might be given:

(a) It should be located near the headgate, but below all sluice gates, and above all delivery gates of the ditch, where practicable.

(b) It should be located in a straight part of the channel, where there are no curves for at least one hundred feet above and below.

(c) It should be set to the true grade of the ditch; that is, to the grade which the ditch takes when carrying water at its normal stage. If practical grade and the theoretical grade are the same, so much the better.

(d) The floor should be smoothly laid, and the bottom of a cross section of the flume should be level.

(e) The sides of the flume may be either vertical or flaring, with a slope of one foot horizontal to one foot verti-

cal. The latter form is preferred by many engineers, as it conforms more closely to the usual form of ditch. In the former case the width should be equal to a little more than the bottom width of the ditch, so that there may be no material contraction at the head of the flume. On the other hand, the flume should not be so wide as to practically broaden the ditch and so cause a slackening of the current, and consequent eddies. In general its width should be equal to the bottom width of the ditch plus the depth of water which it is intended that the ditch shall carry, an amount equal to one-half the depth being added to the bottom width of the ditch on each side of the flume.

Where flaring sides are used, the bottom width should be the same as the theoretical bottom width of the ditch. In either case the cross section of the flume should be practically equivalent to the cross section of the ditch both above and below it.

(f) The sides should be high enough to contain all the water when the ditch is carrying its maximum capacity.

(g) The length of the flume should be not less than twelve feet for ditches whose bottom width is six feet or less, nor less than sixteen feet for ditches between six and twelve feet in width, and twenty-four feet for widths of from twelve to twenty-four feet. For very large ditches the length should not be less than the width of the ditch.

(h) Both floor and sides should be nailed smoothly and with no projecting nails, timber or obstructions of any kind. The material used should be heavy enough so that there may be no danger of the sides being pressed inward by any pressure from without, or of warping or twisting out of shape. A very common error is the use of too light planking in the flume, resulting in its speedily getting out of shape.

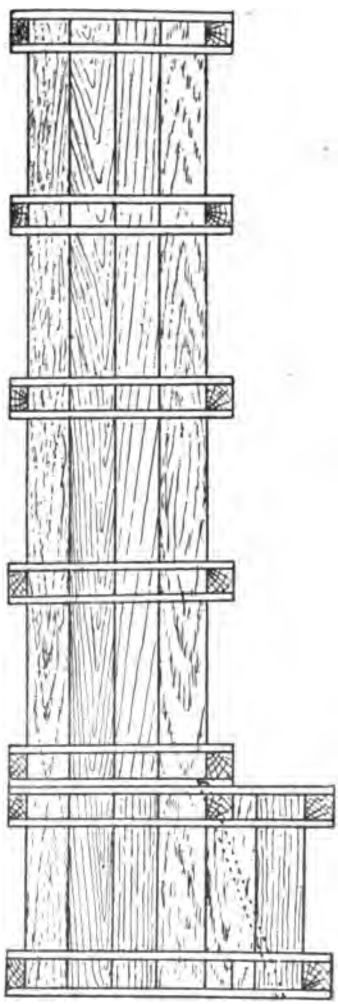
(i) A scale should be marked upon, or cut in, one or both sides, which should be marked in spaces equal to one-tenth of a foot, vertical measurement, and every foot-mark of the scale should be numbered. This can best be done with brass-headed nails, or metal figures, driven deeply into the wood. The zero of the scale should be level with the floor of the flume, and the scale should be marked plainly enough so that the depth of the water may always be read upon the scale from the opposite side of the channel. The scale should be flush with the sides, so that trash of any kind may not catch upon it. It should be located at the center of one or each side of the flume. Rods or scales nailed upon the sides

of the flume should not be tolerated, as they are too easily moved, thus permitting of fraud, and because they present an appreciable obstruction to the flow of the water, making accurate readings difficult, if not impossible.

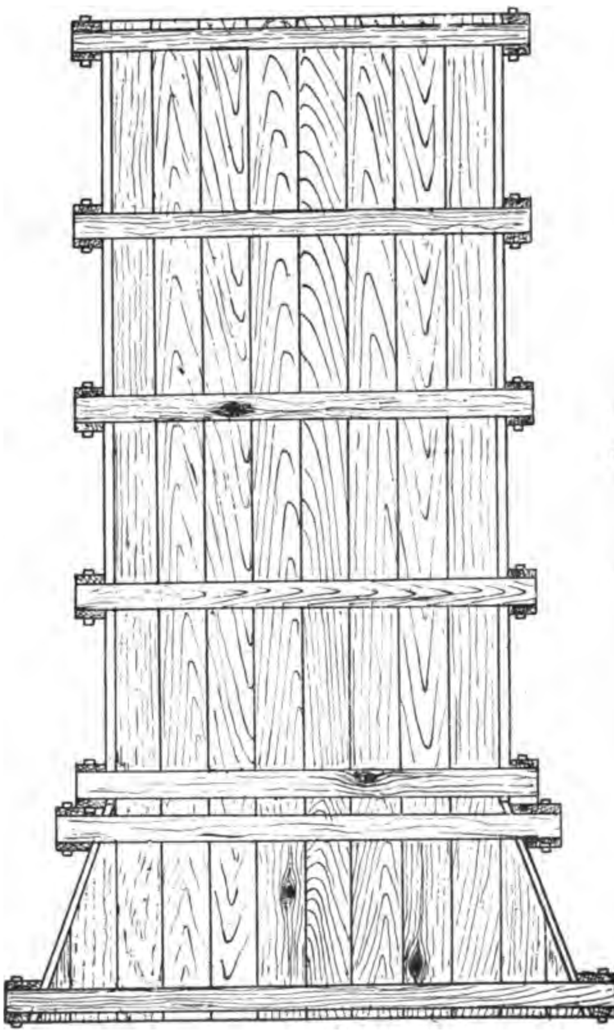
(j) The flume should have cross beams, or bridges, just above or below the gage rod or scale, for convenience in making measurements.

(k) The flume should be protected from leakage around the sides and under the bottom, by suitable wings and aprons.

Plans and specifications for measuring flumes will be found on pages 185, 186, 187 and 188.



RATING FLUME NO. 1. ELEVATION.



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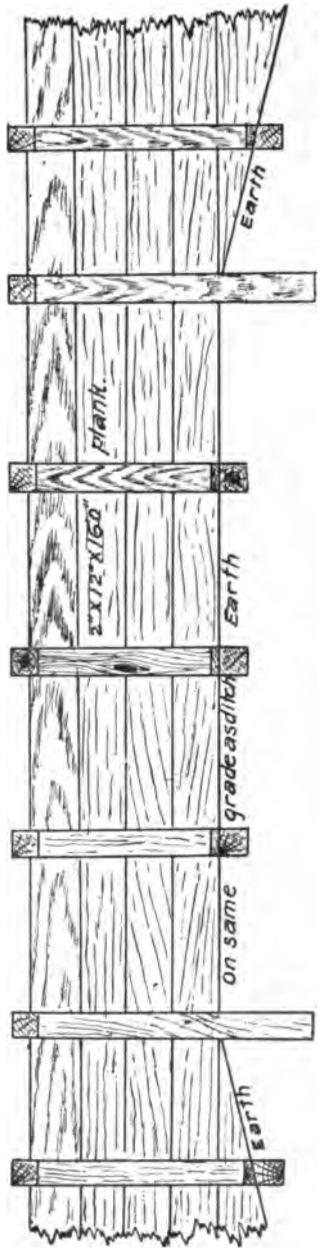

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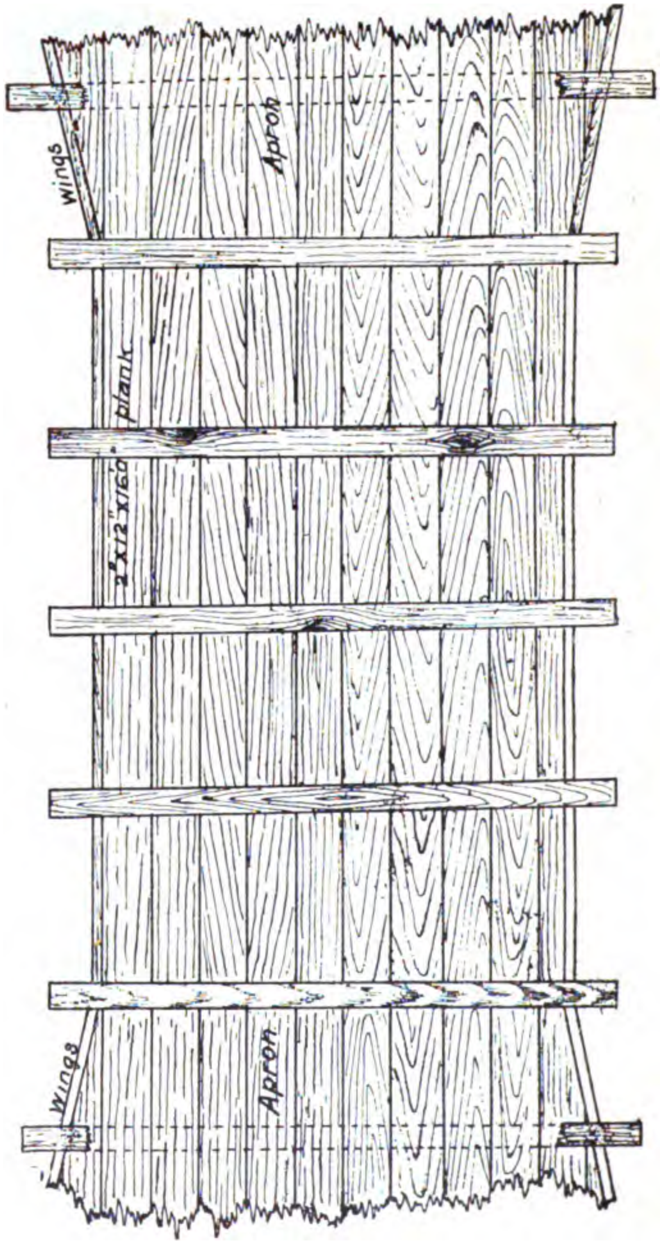


RATING FLUME NO. 2. PLAN.

MEASUREMENT IN FLUMES.

Having a flume in which it is desired to compute the flow of the water, it should first be ascertained that the conditions are as nearly perfect as may be practicable. Cases often occur in which some of the conditions can not be—or at least are not—complied with. In cases where the difficulties can not be avoided, the best that can be done under existing circumstances may be to treat the flume as an ordinary ditch, following the method to be described hereafter for measuring water flowing in open ditches; but whenever it is possible, existing evils should be remedied before any measurements are made. In the first place, the surface of the water must not be rising or falling, either one of which conditions would affect the result to a greater or less degree, the former by giving a discharge greater, and the latter or falling stage by giving a less, than the normal for the given height.

Three methods for determining the velocity will be considered: First, by means of floats; second, by means of a current meter, and third, through a knowledge of the dimensions and grade of the ditch. In each instance the formula for the discharge is already given, namely, $D=A\times V$; therefore, in each case it is first necessary to measure the area of a cross section of the flume at its most favorable point. This is accomplished by measuring the depth at intervals throughout the entire width, usually at every two or five feet, but the intervals will depend upon the width. For a narrow flume it may be necessary to make the measurements every foot, or even less. Of course, if the bottom is known to be level, one or two measurements of the depth may be all that are necessary, but unless this is known to be a fact it will usually be safer to make the measurements all the way across. The width, both of the surface of the water and of the bottom of the flume, at right angles to the direction of the current at the point of gaging, must also be ascertained, and the average depth multiplied by the average width will give the area, or "A" of the formula.

It now remains to measure the velocity, or "V;" this may be done, first, roughly, by floats. A certain distance along the line of the flume is first to be measured, the longer the better, and the number of seconds counted which it takes floats to pass over this measured distance; these floats should be placed in the center and on each side of the center of the

current, and they should be heavy enough to sink almost entirely in the water, so as to be affected as little as possible by currents of air. In general, it is best that all measurements of water in open channels should be taken where there is little, if any, wind blowing, as every breeze strong enough to ruffle the surface of the water will have a greater or less effect on the velocity. Having found by experiment where the current is the swiftest, the maximum velocity must be found; that is, the shortest time that it will take the floats to pass along the measured distance. This distance, divided by the number of seconds and fractions of a second required, will give the maximum velocity per second. Suppose, for example, that the measured distance is twenty feet, and the shortest time required for the float to pass along this twenty feet is $5\frac{1}{2}$ seconds; then, $20 \div 5\frac{1}{2} = 3.64$ (about)=the maximum velocity. Now it has been demonstrated, as the result of many measurements, that the average velocity, which is the "V" of the formula, is equal to from 88 to 93 per cent, of the maximum velocity for flumes in good condition, so that for general purposes we may take 90 (close enough) per cent. of the maximum velocity to get "V." In the case just given, $3.64 \times .90 = 3.276$, or "V." If the average depth of water in our flume was 2 feet, and the average width was 8 feet, we should have the area, or "A,"$=2 \times 8 = 16$, and $D = 16 \times 3.28 = 52.48$ cubic feet per second. It should, however, be remembered that the relation of the surface velocity to the mean velocity will vary with the nature and dimensions of the flume, the latter running anywhere from 95 per cent. down to 75 per cent. of the former, and for accurate results, different percentages, depending upon existing conditions, should be taken. For a full discussion of this point see Fanning's Treatise on Hydraulic and Water Supply Engineering, under the heading, "Ratio of Surface to Mean Velocity."

The second method of determining the average velocity, which we shall consider briefly, is by means of a current meter, and gives, when properly used, the most accurate results of the three. A current meter is an instrument by means of which the velocity of a stream is determined. There are a number of different forms, any of which will give excellent results, of which only a few will be mentioned. One form is made and sold by J. S. J. Lallie, of Denver, which is very satisfactory, and others are sold by W. & L. E. Gurley, of Troy, N. Y.; C. L. Berger & Sons, of Boston, Mass., and others. The cost of a meter varies from $50.00 to $200.00, according to size and fineness of finish. Descriptions of the

various kinds will be found in Fanning's Treatise upon Hydraulic and Water Supply Engineering, already mentioned, and also in an excellent article upon stream measurements, beginning upon page 17 of Part IV of the Nineteenth Annual Report of the United States Geological Survey, which will be found to be of interest in connection with this subject.

RATING THE METER.

We will suppose that a measurement is to be made in a flume by means of a current meter. In the first place, the use of the instrument must be well understood, and it must be known to be in good adjustment and to give results corresponding to the rating table, with which it must already have been provided. The method of rating a meter which should be followed, both whenever an instrument is newly purchased, and whenever it has had to undergo any important repairs, is to pass it at known rates of speed through a measured distance; as, for example, 100 feet. The number of revolutions for each second at a number of different rates of speed, and the distance passed over for each revolution, having been found, a table is made up showing the velocity in feet per second corresponding to revolutions and fractions per second. For example, a part of the rating table of a certain meter belonging to the United States Geological Survey, and in present use in this office, is as follows:

RATING TABLE FOR METER NO.........

FROM OBSERVATIONS MADE.., 189..., AT THE RATING STATION AT CHEVY CHASE, MARYLAND, BY... ...., COMPUTATIONS MADE BY............................... ....

.... DESCRIPTION OF METER, NEW LARGE PRICE.

Revolutions Per Second	Velocity Per Second	Revolutions Per Second	Velocity Per Second	Revolutions Per Second	Velocity Per Second	Revolutions Per Second	Velocity Per Second
....	....	1.00	3.45	2.00	6.57	3.00	9.64
.05	.22	1.05	3.60	2.05	6.70	3.05	9.80
.10	.39	1.10	3.76	2.10	6.85	3.10	9.95
.15	.56	1.15	3.91	2.15	7.01	3.15	10.11
etc.	etc.	etc.	etc.	etc.	etc.	etc.	etc.

The process is theoretically a simple one, but great pains and many measurements must be made to insure accuracy in the table.

MAKING THE MEASUREMENT.

The total width having been already measured, the observer will decide as to how many sections he wishes to divide the total cross section into; for example, if the flume is ten feet wide, each two feet may be made a section to be measured separately; if twenty feet in width, each section may be five feet in length; in other words, the number of sections will depend upon the width of the stream, although it should be said that the shorter the sections are, the more accurate will be the results. Whenever it is possible the measurements should be made from above, from a bridge or from cross pieces of the flume along which a tape line or measuring chain is stretched, giving the sections and points at which the depths have already been measured in the same way that has been described under "Measurement in Flumes." It seems hardly necessary to say in this connection that if the sides of the various sections correspond with the points at which the depths have been taken, the calculations may be more readily performed, this being applicable to measurements in all kinds of open channels.

When measurements are made by wading, a method to be deprecated whenever it can be avoided, the observer should endeavor to hold the meter far enough from himself so that the current may be affected as little as possible by the obstruction which he presents. This is particularly important when ditches are being rated, a subject which will be treated briefly hereafter. (See page 204.) The time may be taken either by means of a stop watch, or with an ordinary watch supplied with a second hand. Theoretically, the work will be more accurate if a stop watch is used, but practically there will be so little difference in the results obtained by the two methods that there will be but little choice between them, and, unless the work is being done by an expert, the ordinary watch will usually be the more satisfactory; both, however, will be described briefly, the first to be considered being the method with the stop watch.

Commencing with the first section to be measured, place the meter just below the surface of the water, noticing particularly that the vanes or cups are entirely submerged, at the side of the flume but still far enough from it so that there shall be no danger of the cups touching the sides. As soon as the

gager is ready, the stop watch should be started and the meter thrown into gear at the same instant, if a geared meter is used, or the electric current turned on if a register is used, or the observer should begin counting revolutions if a sounder is used, and at the same time he should begin to lower the meter slowly in a vertical line until it touches the bottom; it should then be lifted and at the same time carried in a diagonal direction until it reaches a point just below the surface at the outside limit of the section being measured; it should then at once be lowered vertically again until it once more touches bottom, upon which it is again brought diagonally to the point of beginning. The instant it shall reach that point the instrument must be thrown out of gear in the one case, or the observer must stop counting in the other, and the watch must be stopped at the same time. The number of revolutions and the number of seconds consumed must now be noted in a book previously prepared for the purpose. The method of moving the meter will be better understood by a glance at the accompanying diagram. (Fig. 1.)

In this diagram the meter follows the course of the dotted line. Care should be taken that the motion is slow and regular; ordinarily the time consumed should be from twenty to thirty seconds. Two trials should be made at each section, and the results of the two should not vary from each other by more than 2 per cent. If there is a greater variation than that, other trials must be made until the results are within the prescribed limits for two consecutive measurements. By "the results" is meant the number of revolutions per second, which will be found in each case by dividing the number of revolutions by the number of seconds, and carrying the quotient out to two places of decimals. The method of keeping the record can best be explained by the accompanying example of a part of a double page of actual notes taken with a self-recording meter and register. (See page 196.)

The observer will now pass to section No. 2, of which he will get the velocity in the same way, proceeding in this manner throughout the entire width of the flume. The discharge of each section is now obtained by multiplying its area by its measured velocity, which will in this case be its average velocity. The discharge of each section having been found, the different discharges, added together, will give the total discharge of the stream, as is also shown on page 196. In case it is desired to find the average velocity for the entire stream, it will be found by dividing the total discharge by the total area, as there shown.

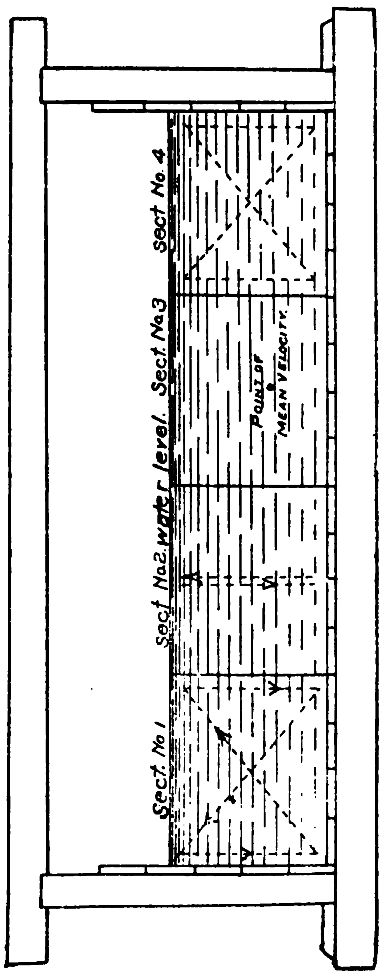

Sect. No. 4
Sect. No. 3
Sect. No. 2. water level.
Sect. No 1
Point of
Mean Velocity.

FIG. 1.

MEASUREMENTS

Made May 11, 1898, by A. L. Fellows. Meter No. 60, at Station 474, at Fall Creek on San Miguel River. Gauge height: beginning 3.3 feet, ending 3.3 feet, mean 3.3 feet. River stationary, total area 72.5 square feet. Mean velocity 3.73. Discharge 270 second-feet.

SOUNDINGS		OBSERVATIONS									SECTION				REMARKS
Distance from Initial Point	Depth	Distance	Depth of Observation	Time in Seconds	Register Reading: Beginning	Register Reading: Ending	Register Reading: Difference	Revolutions per Second	Velocity at Depth of Observation	Average Velocity per Second	Width	Mean Depth	Area	Discharge of Section	On Condition of Channel, Wind, Equipment, Gauge, Boat, Cable, Methods, Accuracy, Etc.
.00	1.4	0	Integrated	Fifty	608 638	638 668	.30 .30	0.60	2.13	3.53	5	1.7	8.5	30.0	
5	2.0	5			668 774	744 820	.76 .76	1.52	4.93	5.05	5	2.0	10.0	50.5	
10	1.9	10			820 900	900 980	.80 .80	1.60	5.17	4.14	5	1.7	8.5	35.2	
15	1.5	15			980 026	026 072	.46 .46	0.92	3.11	3.23	5	1.3	6.5	21.0	Channel fair. Gentle wind up. Equipment fair. Gage O. K. Gage from bridge. Results good. Center of channel somewhat broken by boulders.
20	1.1	20			072 122	122 172	.50 .50	1.00	3.45	2.92	5	1.1	5.5	16.1	
25	1.1	25			172 208	208 244	.36 .36	0.72	2.50	2.25	5	1.3	6.5	14.6	
30	1.5	30			244 272	272 300	.28 .28	0.56	1.99	3.96	5	1.4	7.0	27.7	
35	1.3	35			300 393	393 485	.93 .92	1.85	5.93	5.97	5	1.1	5.5	32.8	
40	1.0	40			485 579	579 673	.94 .94	1.88	6.02	4.72	5	1.0	5.0	23.6	
45	1.0	45			673 724	724 775	.51 .51	1.02	3.41	2.78	5	1.0	5.0	13.9	
50	1.0	50			775 806	806 836	.31 .30	0.61	2.16	1.08	5	0.9	4.5	4.9	
55	0.8	55					.00	.00	.00		55		72.5)	270.3(	3.73

The usual method with the ordinary watch is exactly the same, excepting that a definite length of time is taken; as, for example, fifty seconds, which is the length preferred by the writer, and regulating the movement of the meter so that it shall have as nearly as possible the same amount of time in each part of the section, which can be accomplished with great accuracy after a little practice. Where there is little difference in the velocity of the two sides of the section, the observer may sometimes keep the meter moving up and down in the center of the section, observing the same care as in the former instance. (Fig. 1, Sec. 2.) The variation between the two ways will ordinarily be very slight for the center sections, but the first method is recommended for the side sections of the flume.

Instead of moving the meter up and down in the water, another method is sometimes pursued, especially when the bottom of the channel is smooth, in which case the results will be quite satisfactory. It has been demonstrated that in streams of from a few tenths up to three or four feet in depth, at a point located about three-fifths of the depth below the surface, the velocity is generally equal to the average velocity. Accordingly the meter is placed at that depth below the surface and the velocity measured, the result being taken for the average velocity. While this method applies best to flumes, it is sometimes satisfactorily applied to the measurement of rivers, especially such as are shallow. (Fig. 1, Sec. 3.)

The velocity may also be found for each foot, or other unit of depth, and the results averaged. The first process described, which is known as the "integrating process," will usually give the most satisfactory results, however. Experience will show various other methods, more or less accurate, which may be followed by the gager, but in general it will not be wise for beginners to experiment too much with the current meters.

Computing the discharge by means of the grade and dimensions of the ditch is the method usually employed by hydraulic engineers for getting the theoretical discharge for new ditches or enlargements, and can be treated here only in the briefest manner possible, and as the methods are similar for all kinds of open channels, the subject will be treated in general terms. For more detailed information, with demonstration of formulæ, the reader is referred to J. T. Fanning's Treatise on Hydraulic and Water Supply Engineering, Trautwine upon Hydraulics in his Engineers' Pocket Book, and Wilson's Manual of Irrigation Engineering. Among smaller and inexpens-

ive books upon this subject may be mentioned "Water and Water Supply," by Professor W. H. Corfield, M. A., and "Flow of Water in Open Channels, Pipes, Sewers, Etc., with Tables," by P. J. Flynn, C. E. Both of these booklets are published in the "Van Nostrand Science Series," at 50 cents each.

KUTTER'S FORMULA.

The method preferred by the writer for determining the theoretical flow in open channels is that depending upon a formula of Messrs. Kutter and E. Ganguillet, eminent Swiss engineers, which is usually known as "Kutter's Formula." Here, as in previous cases, the area may be determined by measurements as heretofore explained, or may depend upon the theoretical dimensions of the ditch or flume. It remains, however, to find the velocity, or "V," which is found by the following method:

The formula for velocity as derived from theoretical conditions, without going through the process by which it is obtained, is,

$$V = C\sqrt{R\,S}$$

where "S" equals the slope or fall of the channel per foot, "R" is the "mean radius in feet," explained later, and "C" is a coefficient or factor depending upon the shape of the channel, the character of the sides and bottom, and the slope or fall of the channel. According to Kutter's formula,

$$C = \left\{ \frac{41.6 + \dfrac{.00281}{\text{slope}} + \dfrac{1.811}{N}}{1 + \dfrac{\left(41.6 + \dfrac{.00281}{\text{slope}}\right) \times N}{\sqrt{\text{mean radius in feet.}}}} \right\}$$

Where by slope is meant the fall of the channel per foot and "N" is a "co-efficient of roughness" depending upon the shape and nature of the sides and bottom of the channel.

The following table is given by Trautwine:

TABLE OF N, OR CO-EFFICIENT OF ROUGHNESS.

(a) For artificial channels of uniform cross section:

	N=
Sides and bottom of channel lined with well-planed timber	.009
Neat cement, glazed pipes and very smooth iron pipes	.010
Plaster of 1 of sand to 3 of cement, or smooth iron pipes	.011
Unplaned timber applies also to ordinary iron pipes	.012
Ashlar or brick work	.013
Rubble	.017
(b) Channels subject to irregularity of cross section:	
Canals in very firm gravel	.020
Canals and rivers of tolerable uniform cross section, slope and direction in moderately good order and regimen and free from stones and weeds	.025
Having stones and weeds occasionally	.030
In bad order and regimen, overgrown with vegetation and strewn with stones and detritus	.035

The "mean radius in feet," which is the "R" of the formula $V=C\sqrt{R\,S}$, is found by dividing the area of the cross section by the sum of the "wetted perimeter," which in turn is equal to the sum of the bottom and sides up to the surface of the water of the channel; or, expressing it as a formula,

$$R=\frac{A}{P}$$

in which A equals the "area" and P the "wetted perimeter" of the cross section. In general, it is best to compute the value of "C" for each individual case, but for the convenience of those who do not wish to make the calculation, the following table of approximate values of "C" is given for channels whose fall, or "S," equals .001 per foot, or 5.28 feet per mile:

TABLE OF VALUES OF C FOR MEAN RADII IN FEET.

Where Slope, or S, = .001 Foot per Foot = 5.28 Feet per Mile.

Mean Radius R in Feet	Coefficient N of Roughness											
	.009	.010	.011	.012	.013	.015	.017	.020	.025	.030	.035	.040
.1	108	93	82	73	65	53	45	36	27	21	17	14
.2	128	112	99	89	80	66	57	46	34	27	22	19
.3	141	124	110	99	89	75	64	52	39	31	25	22
.4	150	132	118	106	97	82	70	57	44	35	29	24
.6	161	142	128	115	105	90	77	64	49	39	33	28
.8	169	150	134	122	112	95	82	68	53	43	35	31
1.	174	156	141	128	117	99	87	72	56	45	38	33
1.5	184	165	149	136	125	107	94	79	62	51	43	37
2.	191	171	155	142	130	112	99	83	66	55	46	40
3.	199	179	162	149	138	119	105	89	71	59	51	45
4.	204	184	167	154	142	123	109	93	76	63	55	48
6.	210	190	173	160	148	129	115	99	81	68	59	52
8.	214	193	177	163	151	133	118	102	84	71	62	55
10.	218	197	181	167	155	137	122	106	87	75	66	58
15.	222	201	184	170	158	140	125	109	90	78	69	61
20.	226	205	188	174	162	144	129	113	94	81	72	65
30.	229	208	191	177	165	147	132	116	97	84	75	68
50.	233	212	196	183	170	152	137	121	102	88	79	72
100.	237	216	199	186	172	155	141	124	106	93	84	77

EXPLANATION OF TABLE FOR C.

In order to use this table, the slope, "S," must be known; the mean radius, "R," must be ascertained, and the co-efficient, "N," must be chosen from the table for "N" already given on page 199.

Although the table is calculated for a grade of 5.28 feet per mile, it may be used with approximate accuracy, giving within a small percentage of the theoretical results for all streams and ditches having grades between two feet and fifty feet per mile, which will cover all ordinary cases. Particular care should be exercised in the selection of "N," as there is generally a tendency to make "N" too small, not making allowance for obstructions in the stream. In cases where the value of "R" lies between two of the values given in the table, "C" may be found by proportion between corresponding values of "R" and "C."

EXAMPLE.

Find the discharge for a flume of unplaned timber, the grade of which is 10.56 feet per mile, the average depth of the water being three feet and the average width of the stream being eight feet. In the formula already given,

$$V = C\sqrt{R \times S},$$

$$R = \frac{\text{area}}{\text{wet perimeter}} = \frac{A}{P} = \frac{3 \times 8}{3 + 8 + 3} = \frac{24}{14} = 1.7, \text{ and}$$

$$S = 10.56 \text{ feet per mile} = .002 \text{ foot per foot.}$$

To find "C" take $N = .012$ from the table on page 199, that being the value of N for flumes of unplaned timber, and having found $R = 1.7$, take the nearest value of R in the table for C, which is 1.5, and opposite this value under .012, the value of N, we find C given as 136, and similarly, if R had been equal to 2, C would have been found to be 142, the difference between the two values being $142 - 136 = 6$. As the actual value of R is 1.7, which is two-fifths way between 1.5 and 2.0, it is evident that to find the value of C corresponding to $R = 1.7$, we must add two-fifths, or $0.4 \times 6 = 2.4$, to 136, giving us 138 for the true value of C, or $C = 138$. Substituting in the formula,

$V = C\sqrt{R \times S}$, the respective values of C, R and S, and we have
$V = 138\sqrt{1.7 \times .002} = 138\sqrt{.0034} = 138 \times .06$, approximately.
$V = 8.28$ feet per second. Now as
$D = A \times V$, we have
$D = 24 \times 8.28 = 198.72$ cubic feet per second.

It will be seen from this that although C may remain practically constant for the different slopes, the value of V being dependent upon the slope, will vary widely for streams of the same dimensions. For example, in the problem just given, all the other conditions remaining the same, but S equaling .0005, or 2.56 feet per mile, V would have equaled 4.00, and we would have had $D = 96$ second feet.

Where streams or ditches or flumes with sloping sides are to be considered, care must be taken that the full value of the wet perimeter, or P, is found. For example, if we have a stream the bottom of which measures 20 feet, of which the banks have slopes of one and one-half to one ($1\frac{1}{2}$ to 1), the depth of the water being three feet, we shall have $P = 20 + 5.4 + 5.4$, 5.4 being the length of a line drawn in a vertical plane from the bottom to the surface of the water at the edge. (See Fig. 2.)

Here P is shown by the heavy line, the height and width on the bottom being shown by dotted lines. The value of the line AC is in this case found either by direct measurement of, or by calculating the hypotenuse AB of the right-angled triangle ABC, in which CB equals the depth $= 3$, and AC equals the base $= 3 \times (1\frac{1}{2}) = 4.5$.

$$\begin{aligned} &\text{The square of } 3 &&= 9. \\ &\text{The square of } 4.5 &&= 20.25 \\ \hline &\text{The sum of the two} &&= 29.25, \\ &\text{Of which the square root} &&= 5.4 = AB. \end{aligned}$$

MEASUREMENT OF FLOW IN ROCK CUTS.

As a general proposition, measurements should never be taken in rock cuts where the sides and bottom are rough and jagged. In cases where it does become necessary to make measurements under these conditions, a place should be found where the sides are as smooth as possible, and the observer will then proceed as in a flume, excepting that he will take the higher values of N corresponding to the conditions under which the work is being done. So great an influence does

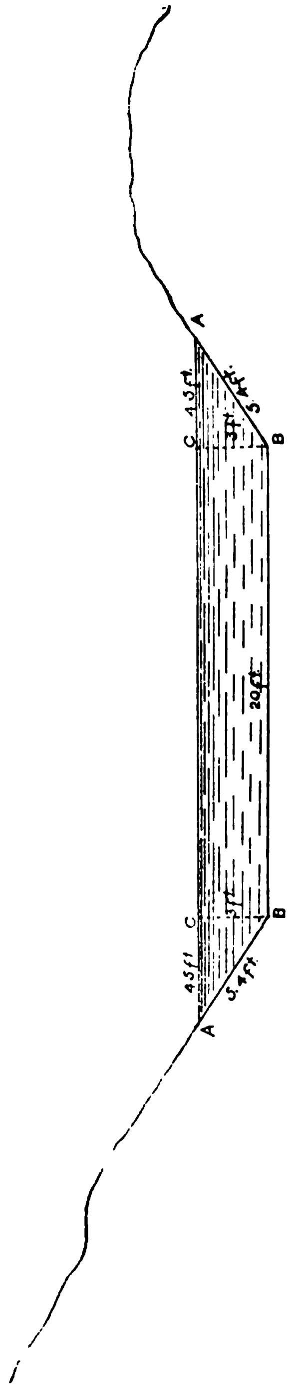


FIG. 2.

the factor N have upon the discharge, that cases sometimes occur in which it is possible to increase the discharge by putting a flume inside the rock walls, or by putting in cement and concrete lining, making the walls and bottom surface smoother, though lessening the cross section. In other words, the decreased cross section may be more than compensated for by the increased average velocity. The methods of measuring the flow being practically identical with those already described for flumes, it is unnecessary to repeat them.

MEASUREMENTS OF FLOW IN EARTH CHANNELS.

The principles of measurements in earth channels are the same as those already given for flumes, but the conditions are so different that it is thought best to take the subject by itself, referring to the former articles for the methods to be pursued.

In the first place, a point should be selected where the conditions should correspond as nearly as may be possible to those recommended for flume measurements, namely, that there should be no eddies or backsets to the current, either at the sides or bottom, and there should be the least possible obstruction from weeds and similar sources.

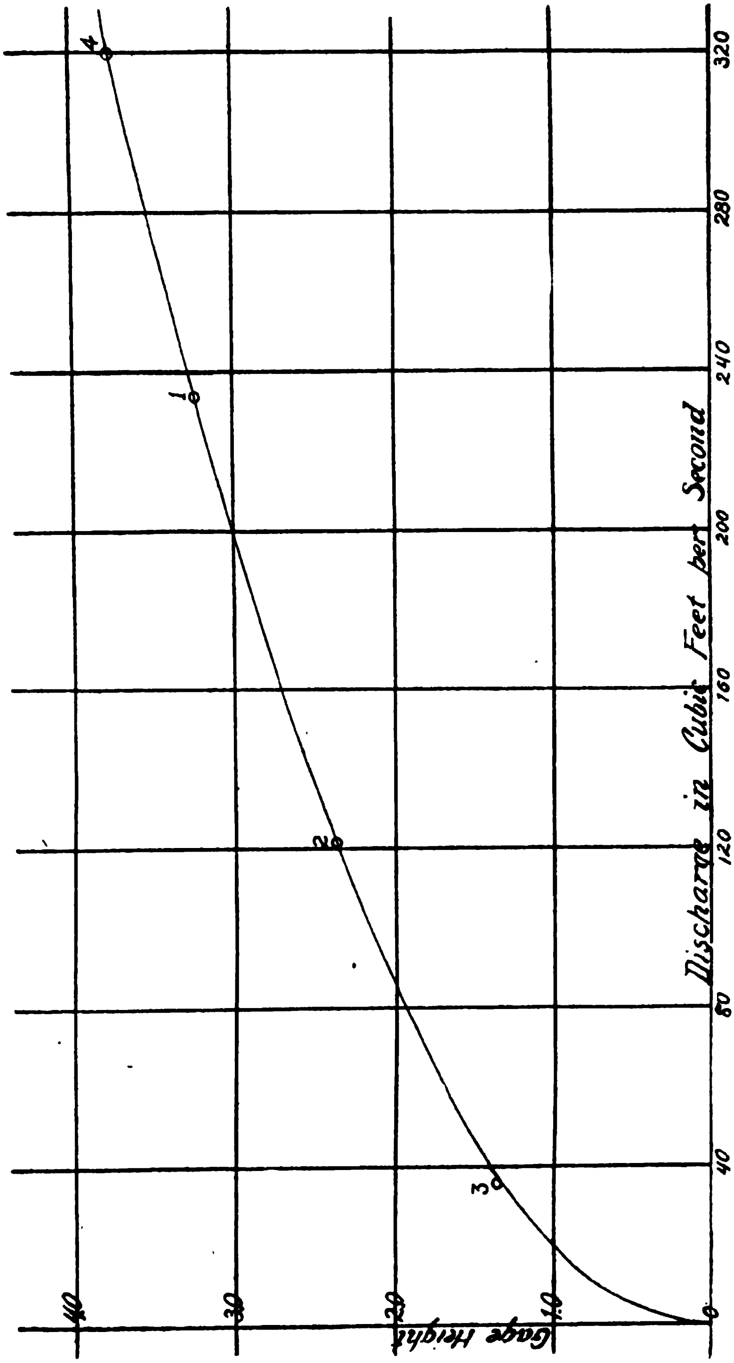
In measuring the area of the cross section, greater care should be taken than in the case of the flume, owing to the unevenness of the bottom.

If the maximum velocity is found, whether by floats or otherwise, 80 per cent. of it should be taken for the average velocity, instead of 90, as there is much greater friction along the sides and bottom than in the flume. In other respects, the method to be pursued is the same.

In case a current meter is used, great care should be exercised in getting the velocity of the sections nearest the water's edge. It will be found that while there is practically no current at the edge, the velocity usually increases much more rapidly than the depth. There can be no fixed rule for the increase, however, and the safest way is to make the sections quite small near the edge. In general, the methods already described must be carefully followed.

RATING OF DITCHES.

To rate a flume or a ditch, is simply to ascertain the discharge of the given conduit for different depths of water flowing through it. The depths should be indicated by the level surface of the water upon a gauge scale placed or marked as



RATING CURVE OF LAKE CANAL.

described in the directions for constructing rating flumes. In general, only flumes should be rated, as ordinary ditch banks and bottoms are too unstable, but it may sometimes be necessary to rate ditches as though they were flumes. The water should first be turned entirely out of the ditch and the nature of the bottom and the reading upon the gauge scale of any water left standing, before it has had time to evaporate or drain off, should be noted. The reading upon the scale will be 0.00 if it is properly set and the ditch or flume is under proper conditions for rating. A certain amount of water is then turned in, say about one-third or one-fifth of the capacity of the ditch, and after the water has ceased to rise in the ditch and is flowing normally without perceptible change on the gauge rod, the reading upon the gauge rod is taken with extreme care, and the measurement of the discharge is made. Approximately, another one-third or one-fifth, as the case may be, is now turned in, and after again waiting until no rise is perceptible, another measurement is made as before, and the same process is continued until the full capacity of the canal is reached. The number of measurements will depend upon the size of the canal, a small ditch requiring perhaps not more than three, and a large one possibly six or seven, and taking two or more days' time.

The measurements having been made and the results calculated, the "rating table" may be computed as follows:

The results are first platted upon cross section paper, as shown in the accompanying diagram (page 205), the gage heights forming the ordinates and the discharges the abcissas, any convenient ratio of gage height and discharge being taken. Through the points thus found, indicated on the diagram by 1, 2, 3 and 4, a smooth curve is drawn and the discharge for each unit of gage height, as, for example, each tenth of a foot, is read as the abscissas. For example, to find the discharge corresponding to a gage height of 2.3, or two feet and three-tenths of a foot, we would find where the horizontal line running through 2.3 intersects the curve; the discharge will be found by reading this distance by means of the numbered line at the bottom of the diagram. In the given case the discharge would be 116 second feet. The process will be more clearly understood by a study of the accompanying notes and calculations.

MEASUREMENTS.

Made July 20, 1898, by A. L. Fellows, at Station Opposite Manzanola (Holbrook) at Rating Flume on Lake Canal. Gage Height: Beginning 3.225 Ft., Ending 3.225 Ft., Mean 3.225 Ft. Water Level Stationary. Total Area 71 Sq. Ft. Mean Velocity 3.29. Discharge 233.7 Second-Feet.

SOUNDINGS		OBSERVATIONS								SECTION				REMARKS
Distance from Initial Point	Depth	Distance	Depth of Observation	Time in Seconds	Register Reading: Beginning	Register Reading: Ending	Register Reading: Records in 50 Seconds	Revolutions per Second	Velocity per Second (a)	Width	Mean Depth	Area	Discharge of Section	On Condition of Channel, Wind, Equipment, Gage, Boat, Cable, Methods, Accuracy, Etc.
0	3.225													
		0–2	Integrated	Fifty			44 42	.86	2.21	2	3.225	6.45	14.3	
2	3.225													
		2–4					57 59	1.16	2.97	2	3.225	6.45	19.2	
4	3.225													Meter No. 13.
		4–6					64 65	1.29	3.29	2	3.225	6.45	21.2	Flume clear and in good condition.
6	3.225													
		6–8					66 65	1.31	3.35	2	3.225	6.45	21.6	Bottom of gage-rod = bottom of flume.
8	3.225													
		8–10					66 66	1.32	3.37	2	3.225	6.45	21.7	Depth taken for gage height.
10	3.225													
		10–12					68 69	1.37	3.50	2	3.225	6.45	22.6	Conditions favorable for good results.
12	3.225													Gentle wind up.
		12–14					69 70	1.39	3.54	2	3.225	6.45	22.8	Flume clear when all water is turned out and bottom level
14	3.225													
		14–16					71 71	1.42	3.62	2	3.225	6.45	23.3	
16	3.225													Ditch curves above and below flume.
		16–18					74 73	1.47	3.75	2	3.225	6.45	24.2	
18	3.225													
		18–20					67 69	1.36	3.48	2	3.225	6.45	22.4	
20	3.225													
		20–22					63 61	1.24	3.16	2	3.225	6.45	20.4	
22	3.225													
												70.95)	233.70	(3.29

(a) Taken from Rating Table of that particular meter.

Three similar measurements followed, with gage heights of 2.35, 1.35 and 3.75, giving discharges of 121.4, 36.0 and 319.4 second feet, respectively. In these measurements it will be observed that the gagings were made with each of the three first gage heights less than the preceding one, and with the last stage taken at a considerable time afterward and at the full capacity of the canal. This course may sometimes be necessary, but in general it is better to gage from an empty flume up. It will be noticed, also, that two columns, headed "Begin" and "End," are left blank. These columns are for use where a self-recording register is used. Where a sounder is used, however, as was done in this case, the columns are unnecessary. The measurements having been made and the results computed, a curve was constructed as described above (see diagram), and the rating table given below was then computed from the curve:

LIST OF DISCHARGE MEASUREMENTS.

MADE FROM GAGINGS 1 TO 4, INCLUSIVE, USING SMALL PRICE METER NO. 13.

No.	Date 1898	Hydrographer	Meter No.	Gauge Height	Area of Section	Mean Velocity	Discharge	Remarks
1	July 20	A. L. Fellows	13	3.225	70.95	3.29	233.7	Results good
2	July 20	A. L. Fellows	13	2.35	51.7	2.35	121.4	Results good
3	July 20	A. L. Fellows	13	1.35	29.7	1.21	36.	Results good
4	July 20	A. L. Fellows	13	3.75	82.5	3.88	319.4	Results good

RATING TABLE

BASED ON DISCHARGE MEASUREMENTS, NUMBERS 1 TO 4, INCLUSIVE; APPLICABLE FROM JULY 20, 1899, TILL FURTHER NOTICE.

Gage Height	Discharge	Difference	Gage Height	Discharge	Difference	Gage Height	Discharge	Difference	Gage Height	Discharge	Difference	Gage Height	Discharge	Difference
0.0	0	......	1.0	20	4	2.0	86	9	3.0	200	14	4.0	371	21
0.1	1	1	1.1	24	4	2.1	96	10	3.1	215	15	4.1	392	21
0.2	2	1	1.2	29	5	2.2	106	10	3.2	230	15	4.3	413	21
0.3	3	1	1.3	34	5	2.3	116	10	3.3	245	15	....	....	......
0.4	4	1	1.4	39	5	2.4	126	10	3.4	260	15	....	....	......
0.5	5	1	1.5	46	7	2.5	137	11	3.5	276	16	....	....	......
0.6	7	2	1.6	53	7	2.6	148	11	3.6	292	16	....	....	......
0.7	9	2	1.7	61	8	2.7	160	12	3.7	310	18	....	....	......
0.8	12	3	1.8	69	8	2.8	173	13	3.8	330	20	....	....	......
0.9	16	4	1.9	77	8	2.9	186	13	3.9	350	20	....	....	......

RIVER RATINGS.

Rating tables similar to those made for canals may be constructed for river gaging stations also; here, however, it being impracticable to vary the stage of water at will, the data must be secured at intervals ranging through a considerable period of time.

In locating river gaging stations, considerable care should be exercised in selecting points where the channel is liable to the least possible change, as it is evident that any change will vary the relations between gage height and discharge. Sometimes this ratio will vary so much as to make several rating tables necessary for a single season, or it may even make rating tables impossible, the gaging being valuable simply as isolated measurements. Where it is practicable, permanent gaging stations of timbers or of concrete and masonry should be constructed.

In the ordinary river gaging station, an average curve is drawn upon the plat, results being applicable for a definite period of time, unless a permanent channel has been found. Usually the rating tables thus made are at best but close approximations, but even thus are of great value, and data thus derived is much sought after.

There are several methods that may be adopted for measuring rivers, which will differ to fit the various kinds and sizes of streams. When the stream is shallow it may be waded and excellent results be thus obtained. In deeper streams it becomes necessary to cross by other means. A bridge, for example, may be favorably located for a station, but a number of piers or piles belonging to the bridge will seriously affect the results by breaking up the current and making the cross section irregular. Some of the most satisfactory stations are supplied with steel cables crossing the streams at favorable points, a suspended car or platform carrying the observer across the stream. Both here and in the case of the bridge, if the stations are to be at all permanent, the distances are measured once for all and marked throughout the entire breadth of the stream either by an additional wire, with suitably marked tags or by figures marked upon the bridge.

In case neither of these plans is feasible, the measurements may be made from a boat or catamaran attached to a cable, after the manner of a ferry boat.

The amount of time needed for each observation will also vary widely under different conditions. In general, the larger the stream the longer should each observation take. This is due in part to the fact that in large streams the water flows, to a certain extent, apparently in surges, and in some large streams the fluctuations may consume a minute or more.

A very full discussion of the various methods of making measurements in rivers, with explanatory illustrations, will be found in Part IV of the Nineteenth Annual Report of the United States Geological Survey, pages 19 to 31, inclusive.

DISCHARGE OVER WEIRS.

Mention has already been made of Bulletin No. 27, compiled by Professor L. G. Carpenter, of the Colorado State Agricultural College. It is to that bulletin that we are indebted for much of our information regarding this branch of our subject, and a careful study of the same is recommended to all who are interested in the subject of weir measurements, whether historically or practically. Unfortunately, the edition for distribution is exhausted, but copies may usually be seen in any of the public libraries.

The term "weir" is not always understood by those who use it. The writer has frequently heard it used, even by water commissioners and ditch superintendents, where rating flumes, or even orifices, were intended. The term weir can properly be used only for structures where the water flows over a crest with a considerable fall; it does not apply to dams over which the water is not intended to pass, but wherever provision is made for overflow, that provision is in the form of a "weir."

Measurements of water by means of weirs must, therefore, be of a very different nature from those made in flumes or open channels. In the latter case, the water is flowing for some considerable distance through a uniform channel, with a nearly uniform velocity; in the former case it is usually brought approximately to a state of rest, and then pours over a crest with a velocity dependent upon its depth upon, and the nature of, the crest.

Weir measurements are preferred by most hydraulic engineers to all other forms of measurement, particularly where it is desired that the flow of water should be accurately ascertained. The conditions requisite for good results are not difficult of fulfillment, particularly in comparatively small channels. In fact, good results may be obtained with greater

facility than in any other form of measurement. It is quite possible to obtain results for irrigating ditches of ordinary dimensions that will vary not more than one per cent. from the true discharge. On this account, and because overflow weirs are easily and economically constructed, there is no doubt but that this method will become used more and more as water becomes more valuable. It has been adopted in some states as the official method of measurement; notably, by the state engineers of Utah and Idaho. The first biennial reports of the state engineers of each of these states will be found of interest in this connection, as they give much information in addition to that which it is possible to include in this bulletin. A circular issued by Professor Elwood Mead, irrigation expert of the United States Department of Agriculture, March 1, 1899, giving general instructions to observers, will also be of great value in the construction and use of weirs.

In all the various forms of weirs the conditions to be complied with are similar. Especial cases often occur which require especial consideration, but in general the conditions are as follows:

(1) The weir should be in a plane at right angles to the current of the stream, at a point where the channel is straight for some distance above the weir, and the current, if any be perceptible, should set toward the center of the overflow space.

(2) The water should be brought as nearly as possible to a state of rest above the weir, either by means of a natural lake, or an artificial widening and deepening of the ditch.

(3) Where it is possible, the overflow space should have full contraction, or, in other words, both the sides and the bottom of the face of the weir should have faces at right angles to the current equal to at least twice the normal depth of the water expected to pass over the crest. Cases which have incomplete contraction will be considered separately.

(4) The up-stream side of both the bottom and sides of the weir should be brought nearly to a knife edge, the beveling, or cutting away, being on the lower, or down-stream side, and the bottom edge of the crest should be level.

(5) The width of the crest should be sufficient so that the depth of water passing over it shall not become equal to more than one-third its width; on the other hand, the depth should not be less than three inches for good measurements.

(6) There should be sufficient fall below the weir so that the air may have free access under the sheet of falling water, the sheet not touching the sides of the box or flume in which the weir is placed.

In measuring the depth of water passing over the crest, the level of the still water back of the weir should be considered, and not the water exactly over the crest. In order to find the proper depth, a stake may be driven into the ground in the bottom of the stream a few feet back from the crest until its top is level with the crest; the depth may then be taken either with a gage rod fastened to the stake, its zero mark being level with the crest of the weir, or by placing a rule or square upon the top of the stake, and thus measuring the depth each time. In case it is required to read the depth with great accuracy, the rule or rod may be provided with a slide made of tin or other metal, of the form given in Fig. 3a.

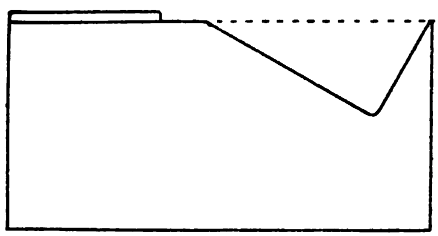


FIG. 3 (a).

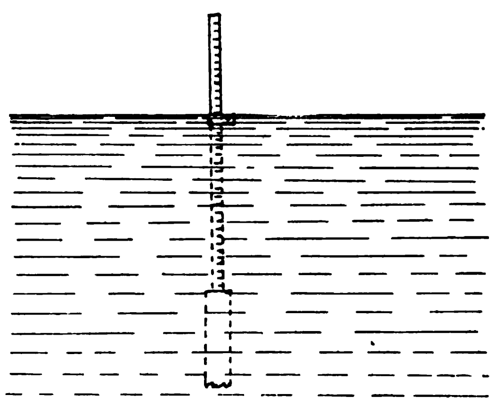


FIG. 3 (b).

The slide is intended to be moved up on the rule from any point below the surface of the water, until the point at

the end of the slide, which must be level with its top, just makes a pimple upon the water's surface. The reading of the upper edge of the slide will now be the reading for the true depth. Care must, of course, be taken that the gage is vertical and that the datum, or zero, of the gage is level with the top of the crest of the weir.

Many things may affect the discharge, but by careful construction most of the evils may be avoided. One of the greatest difficulties is the liability that the channel above the weir may be filled by the deposit of silt up to the level of the edge. This will increase the flow above the theoretical amount, and, where it is practicable, the channel above the weir should be kept clean, the total depth of water just back of the weir never being allowed to be less than three or four times the amount on the edge. The writer has sometimes made use of a weir that may occasionally be taken out of the frame in which it is set, or may even be left out excepting when being used for measurements. He has also made use of an iron weir which may be driven into the ground in small ditches and the discharge ascertained with considerable accuracy. A movable weir like this can, of course, be used for very small channels only.

RECTANGULAR WEIRS.

In this form the slides or shoulders of the weir are vertical and perpendicular to the bottom of the opening. This form of weir, with full contraction, is shown in the accompanying cut. (Figs. 4, 5 and 6.)

Fig. 4 gives a birdseye view of a rectangular weir in place, the observer looking up the stream. Fig. 5 shows the waterfall over the weir, and Fig. 6 gives a section of the waterfall and weir at right angles to the weir. It will be seen that, as the water flows through the opening, the stream becomes contracted at both sides, and also where it passes over the edge. Where both of the shoulders and the crest of the weir are perpendicular to the flow, and the distances AB (Figs. 5 and 6) are equal to at least twice the height H (Fig. 6), the contraction is said to be complete. In case one of the shoulders approaches the opening at an angle, or is missing altogether, or if the floor slopes up toward the edge of the weir, the contraction is incomplete. If there is no narrowing of the channel at the overflow, there is said to be no lateral contraction. If the bottom of the stream is level with the edge of the weir, there is no bottom contraction. Al-

lowance must be made for any of these conditions. The measurements are, however, more satisfactory where there is complete contraction, and hence that form will be the one to be considered most fully.

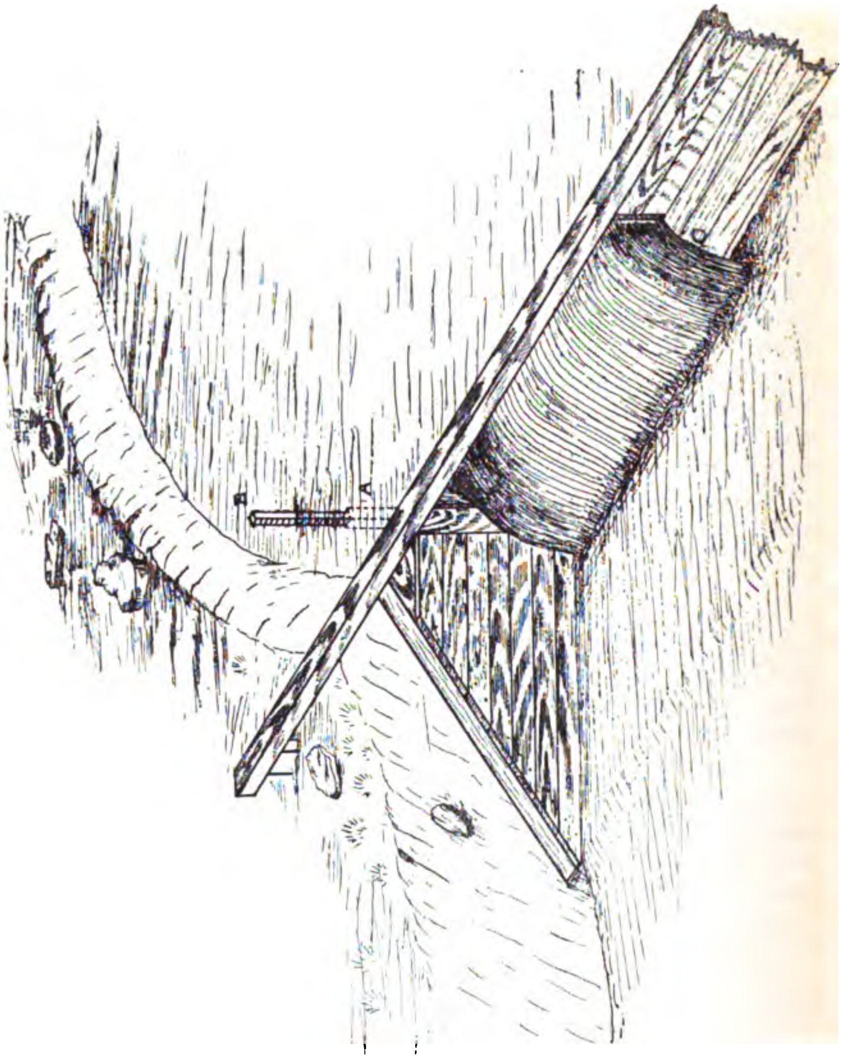


FIG. 4.

A.—Top of Stake Level with Crest of Weir.
B.—Gage for Ascertaining Depth in Still Water.
C.—Air Space Under Water-fall.

FIG. 5.

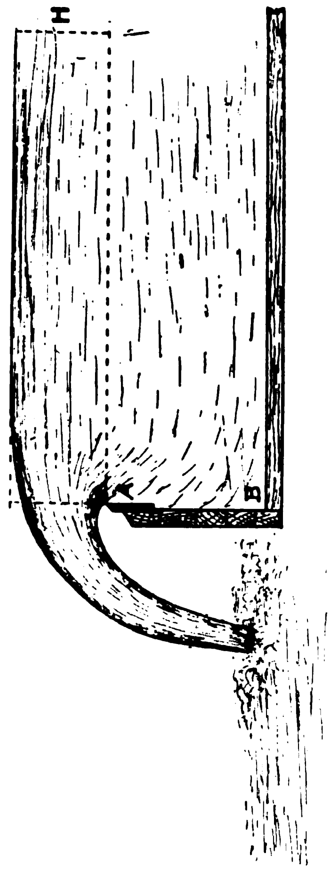


FIG. 6.

It is to the late James B. Francis, of Lowell, Mass., that we owe the generally approved formula for the discharge over weirs. A brief discussion of the methods adopted by Mr. Francis is found in the Agricultural College Bulletin No. 27, already mentioned, as well as in nearly all other works upon hydraulic engineering. The formula, known as the Francis Formula, is as follows:

$$D = 3\tfrac{1}{3}.\, LH^{\frac{3}{2}}.$$

In this equation D = the quantity of water flowing over the weir in cubic feet per second, H = the depth of the water passing over the weir measured some distance back from the crest, as has been previously explained, the measurement being in feet and decimals, and L is the effective length of the crest of the weir, also measured in feet and decimals. The "effective" length is the actual length in cases where there is no side contraction and in the Cippoletti form of weir, but for each side contraction that exists a correction must be applied equal to one-tenth of the depth of water measured on the gage, to be subtracted from the actual length. For the convenience of those who do not wish to make the calculations, a table applicable to weirs in general is here given:

TABLE OF COMPUTED WEIR VOLUMES.

ON SHARP CREST, $Q=3.33\ (L-0.1\ nH)\ H^{\frac{3}{2}}$ (SEE PAGE 215), FOR EACH LINEAL FOOT OF WEIR. (SEE NOTE FOR EFFECT OF CONTRACTIONS AND VELOCITY OF APPROACH.)

Depth, in Feet	*Inches	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
		Discharge Q, in cubic feet per second. Length = 1 ft. n = o.									
.2	2⅖	.30	.32	.34	.37	.40	.42	.44	.47	.49	.52
.3	3⅗	.55	.57	.60	.63	.66	.69	.72	.74	.78	.81
.4	4⅘	.84	.87	.91	.94	.97	1.	1.04	1.07	1.11	1.14
.5	6	1.18	1.21	1.25	1.28	1.32	1.36	1.40	1.43	1.47	1.51
.6	7⅕	1.55	1.59	1.62	1.67	1.70	1.75	1.78	1.82	1.81	1.91
.7	8⅖	1.95	1.99	2.03	2.07	2.12	2.16	2.21	2.25	2.29	2.34
.8	9⅗	2.38	2.43	2.47	2.52	2.56	2.61	2.65	2.70	2.75	2.80
.9	10⅘	2.84	2.90	2.94	2.99	3.03	3.08	3.13	3.18	3.23	3.28
1.0	12	3.33	3.38	3.43	3.48	3.53	3.58	3.63	3.68	3.74	3.79
1.1	13⅕	3.84	3.89	3.95	4.	4.05	4.11	4.16	4.21	4.27	4.32
1 2	14⅖	4.38	4.43	4.49	4.54	4.60	4.65	4.71	4.77	4.82	4.88
1.3	15⅗	4.94	4.99	5.05	5.11	5.16	5.22	5.28	5.34	5.40	5.46
1.4	16⅘	5.52	5.58	5.63	5.69	5.75	5.81	5.87	5.93	5.99	6.06
1.5	18	6.12	6.18	6.24	6.30	6.36	6.43	6.49	6.55	6.61	6.68
1.6	19⅕	6.74	6.80	6.87	6.93	6.99	7.06	7.12	7.19	7.25	7.32
1.7	20⅖	7.38	7.45	7.51	7.58	7.64	7.71	7.78	7.84	7.91	7.97
1.8	21⅗	8.04	8.11	8.18	8.24	8.31	8.38	8.45	8.52	8.58	8.65

TABLE OF COMPUTED WEIR VOLUMES—Concluded.

ON SHARP CREST, $Q=3.33\ (L-0.1\ nH)\ H^{\frac{3}{2}}$ (SEE PAGE 215), FOR EACH LINEAL FOOT OF WEIR. (SEE NOTE FOR EFFECT OF CONTRACTIONS AND VELOCITY OF APPROACH.)

Depth, in Feet	*Inches	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
	Discharge Q, in cubic feet per second. Length = 1 ft. n = o.										
1.9	22⅘	8.72	8.79	8.86	8.93	9.00	9.07	9.14	9.21	9.28	9.35
2.0	24	9.42	9.49	9.56	9.63	9.70	9.77	9.84	9.92	9.99	10.06
2.1	25⅕	10.13	10.20	10.28	10.35	10.42	10.50	10.57	10.64	10.72	10.79
2.2	26⅖	10.87	10.94	11.01	11.09	11.16	11.24	11.31	11.39	11.46	11.54
2.3	27⅗	11.62	11.69	11.77	11.84	11.92	12.00	12.07	12.15	12.23	12.30
2.4	28⅘	12.38	12.46	12.54	12.61	12.69	12.77	12.85	12.93	13.00	13.08
2.5	30	13.16	13.24	13.32	13.40	13.48	13.56	13.64	13.72	13.80	13.88
2.6	31⅕	13.96	14.04	14.12	14.20	14.28	14.36	14.45	14.53	14.61	14.69
2.7	32⅖	14.77	14.86	14.94	15.02	16.10	15.19	15.27	15.35	15.43	15.52
2.8	33⅗	15.60	15.69	15.77	15.85	15.94	16.02	16.11	16.19	16.28	16.36
2.9	34⅘	16.44	16 53	16.62	16.70	16.79	16.87	16.96	17.04	17.13	17.22
3.0	36	17.31	....	....	....	....	....	....	....	....	....

*To the nearest fifth of an inch.

—From Fanning—Treatise of Hydraulic and Water Supply Engineering.

Note—This table is computed for each hundredth of foot-depth from 0.2 to 3.0. The intermediate thousandths of a foot-depth may be readily interpolated. The discharge being given for each lineal foot of weir, the total discharge of the weir will be found by multiplying the quantity here given by the effective length. If there is a velocity of approach divide the weir volume as above by section of channel, in square feet, for approximate velocity, V. Then the additional depth on weir due to this velocity is $h=(v^2 \div 64.4)$. Add to the measured depth 1.5 h for the corrected depth on weir, and then take the volume from the above table for the corrected depth.

The coefficient of h(1.5) becomes 2.05 approximately when there is velocity of approach with end contraction.

TRAPEZOIDAL WEIRS.

It is evident that if some form of weir can be found that will, by divergent sides or in any other way, compensate for these side contractions, it will not be necessary to apply these corrections. It is true, where there is no side contraction, that the actual length is also the effective length, but in this case the correction to be made for the "velocity of approach," as given in the note subjoined to the table, becomes greater and more troublesome. An Italian engineer, Cesare Cippoletti, has devised a form of trapezoidal weir which seems to meet and overcome this difficutly as well as it is possible for any form to do it. In this form, known as the Cippoletti weir, the sides, instead of being vertical, diverge from each other with a slope, or batter, of one in four from a vertical position. This is more fully shown in the cut. (See Figs. 7 and 7 a.)

As will be seen in the cut, the stream of water is affected by the lateral contraction only so much as to make the sides of the contracted vein of water vertical, and the effective length, therefore, equal to the actual length of the crest of the weir, where the conditions already given for the relation of the depth to the width are filled. The formula here used for this form of weir is the Francis formula, as given above, and where D, L and H are the same as in the formula for rectangular weirs, except that L is the actual length of the crest of the weir, no correction for contraction being necessary.

OTHER FORMS OF WEIRS.

Several other forms of weirs have been used, but it is not thought best to more than indicate what they are, as the two most practical forms are those already described. They are usually of a trapezoidal shape, having a batter different from one in four, or of a triangular form in the shape of a notch cut in a plane surface through which the stream passes. The first form is merely a variation of the Cippoletti form, and is not recommended, as the process of calculating the discharge would be different for each different shape. The general equation for triangular notches is:

$$D = 2.65\ T\ H^{\frac{5}{2}}.$$ * (See foot note.)

Here D = discharge, T = the tangent of one-half the angle made by the sides of the notch, and H = the depth

of water passing through the notch in feet, measured as in the preceding cases.

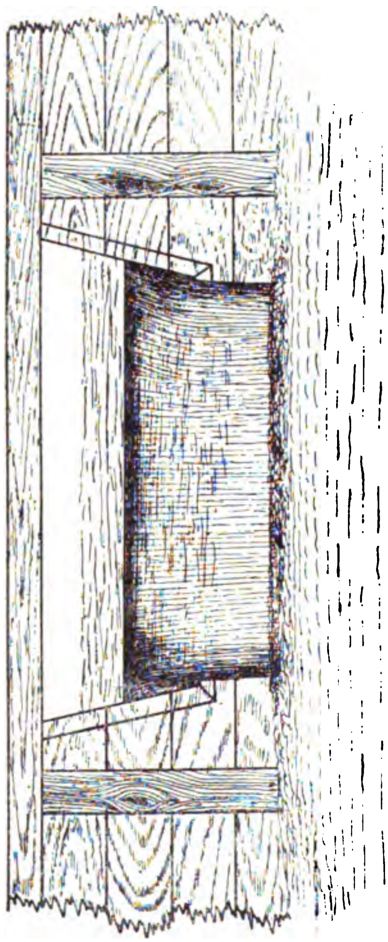


FIG. 7.

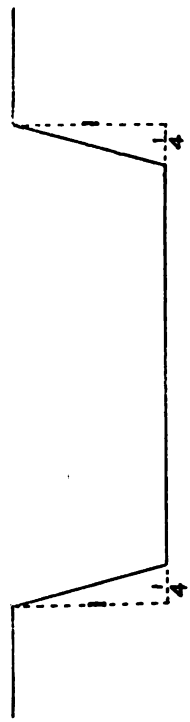


FIG. 7 (a).

Where the angle is a right angle, which is the most convenient form from almost every point of view, the equation becomes $D = 2.65\ H^{\frac{5}{2}}$ power, the tangent of one-half the angle being in that case equal to 1. This form is particularly applicable to quite small streams.

CAUTION.

In all forms of weirs it is clear that it is especially necessary that the bottom of the canal above the weir does not become full of silt. It may be necessary to clean the canal out at times, or it may be possible to make the weir movable, so that the current may occasionally scour the channel out. In any case, to insure accurate measurements, the channel must be clear and the bottom contraction must be complete.

In case the weir is very long, it may be divided by partitions, and each section treated as a separate weir, one depth answering for all weirs, however, if the crest is level. These partitions should, however, be equal to at least four times the normal depth of water passing over the crest.

Persons wishing to make a more thorough study of this branch, or to obtain more exact results than will be obtained from the formulæ given, are advised to make use of Fanning's Treatise on Hydraulics, already mentioned, which treats of nearly every condition liable to arise in ordinary practice.

DISCHARGE THROUGH ORIFICES.

The usual methods of measuring water through orifices are very crude, and usually give results varying a long ways from the truth; hence these are not recommended to parties measuring water for irrigation or for any other purpose. It has already been pointed out that the measurements of inches as used in some states have been very unsatisfactory and incorrect. A brief discussion of the measurement of water through orifices will explain why this is so.

There may, of course, be a great many forms of orifices, in each of which conditions giving the measurement may be to some extent different from those of all the others. The shape of the opening, or of its edges, a free discharge into air, or a discharge into water, or against the sides of the box or trough; the head, the direction and velocity of the current past or toward the opening, are all factors that limit or increase the discharge, and it will be seen that with all these different conditions affecting the flow, the conditions named in the Colorado statute are totally inadequate. Take, for example, the one factor of head. If the other conditions, shape and size of orifice, etc., remain the same, it is evident that the discharge will increase as the pressure or head increases, the ratio being, the discharge increases as the square root of the head; so that in two openings, where

the shape, size and all other conditions were the same, but the head in one case being one foot, and in the other four feet, the discharge in the second case would be twice that of the first, as the square root of 1 is 1, and of 4 is 2. Now as the theoretical "head" must be measured to the center of gravity of the orifice (practically its true center usually), it is evident that the statute is not mathematically accurate when it prescribes measurement to the top of the orifice. Take, for example, two cases suggested by the statute. Let us suppose one opening six inches wide and six inches in height with a five-inch head above the top of the orifice, giving in this case a discharge of 36 statutory inches. Let the next opening be two inches wide and two inches high, with a five-inch pressure above the top of the opening, giving four statutory inches. Now it is clear in the first case that the actual head measured to the center of gravity is 8 inches, and in the second it is only 6, giving a decided advantage to the larger opening. More than that, the area in the first case is 36 square inches, and in the second 4, the ratio being 9 to 1; but the perimeters of the respective openings, upon which the discharges also depend, are 24 and 8, or 3 to 1, equivalent to 9 to 3; so that in the second case the perimeter is three times as great in proportion to the area of the orifice as in the first, thus giving an other very great advantage to the larger opening. This follows, no matter how large the openings are made, although they remain statutory. There is always a discrimination in favor of the larger user, directly contrary to the principles of equity and justice. In the two cases given, the larger opening would actually be receiving about ten and one-half times as much, or almost 12 per cent., more than the second, instead of nine times as much, as the case would be were the statutory requirements all that they should be.

It is evident that it would be impossible either to formulate a rule that would cover all kinds and shapes of orifices, or to give anything like a complete discussion of this branch, in a pamphlet of this nature. We shall endeavor, however, to give a few general rules which will cover orifices under ordinary conditions. As has already been suggested, there are certain conditions that should be fulfilled as nearly as possible. These conditions are much the same as with weirs, so no more than a brief statement of them will be necessary.

First, the water should be brought as nearly as possible to a standstill in front of the opening, so that neither the velocity of approach, nor the velocity past the orifice, may seriously affect the discharge.

Second, where there is a square contraction, it should be complete; that is, the face next to the orifice should be vertical and perpendicular to the direction of the current through the orifice, and should extend at least two or three times the breadth of the orifice back from its edge.

Third, it will be better if the depth over the top of the orifice is at least two or three times the height of the opening, although where the head is measured to the center of gravity, as it must always be to be correct, the top of the orifice, particularly if it be small, may reach nearly to the surface of the water.

In this discussion only cases where the head remains practically constant will be considered, as that is the usual condition under which it is desired to ascertain the flow of water for irrigation. One exception to this rule will be made, however, namely, the calculation of the discharge of reservoirs, which will be described later. With that exception it must be understood that the following tables and rules are applicable only when the surface of the water above the orifice does not materially change.

TABLE

OF THE THEORETICAL VELOCITIES IN FEET PER SECOND FOR WATER FLOWING OUT INTO AIR FROM OPENINGS EITHER IN THE BOTTOM OR SIDES OF A RESERVOIR OF ANY KIND.

This Table is Computed From the Formula: Theoretical Velocity = 8.03 Times the Square Root of the Head in Feet, or

$$V = 8.03\sqrt{H}.$$

Head		Velocity, Feet Per Second	Head, Feet	Velocity, Feet Per Second	Head, Feet	Velocity, Feet Per Second	Head, Feet	Velocity, Feet Per Second	Head, Feet	Velocity, Feet Per Second
Feet	Inches*									
.010	0.1-8	.80	1 ft.	8.03	8	22.7	40	50.7	500	179
.050	0.19-32	1.79	1.20	8.79	9	24.1	45	53.8	600	197
.100	1.3-16	2.54	1.40	9.49	10	25.4	50	56.7	700	212
.200	2.13-32	3.59	1.60	10.2	12	27.8	60	62.1	800	227
.30	3.19-32	4.39	1.80	10.8	14	30.0	70	67.1	900	241
.40	4.13-16	5.07	2.	11.4	16	32.1	80	71.8	1000	254
.50	6.	5.67	3.	13.9	18	34.0	90	76.1	....	....
.60	7.3-16	6.22	4.	16.0	20	35.9	100	80.3	....	....
.70	8.13-32	6.71	5.	17.0	25	40.1	200	114.	....	....
.80	9.19-32	7.18	6.	19.7	30	43.9	300	139.	....	....
.90	10.13-16	7.61	7.	21.2	35	47.4	400	160.	....	....

*Given to the nearest thirty-second of an inch.

DIRECTIONS FOR USE OF TABLE.

In all cases where it is desired to find the discharge by means of the table, through orifices where the head and area of the orifice are known, it will first be necessary to find the theoretical velocity of the water through the opening, or V. Find the number corresponding most closely to the known head, or vertical distance from the surface of the water to the center of gravity of the orifice, in the column designated as "head," and take the number opposite to it under the column designated as "V," or "velocity," for the theoretical velocity. For heads between those given in the table the velocity may be found approximately by proportion. The discharge, or D, should now be equal to V times the area of the opening; but as the effective area is dependent upon the shape and nature of the orifice, a certain percentage, which varies widely in different cases, of the result must be taken to give the actual discharge. This percentage is given for a number of the more ordinary cases, as follows:

For trumpet-shaped openings (see Fig. 8) the percentage may run as high as 95 or 97; in this case,

$$D = V \times \text{Area} \times .96 = .96\ AV.$$

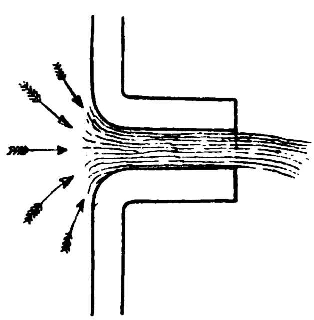


FIG. 8.

In orifices shaped as in Fig. 9, where the angle "a" equals about 5°, or, as in Fig. 10, where the angle "a" equals about 15°, the percentage will be about 92. Here,

$$D = .92\ AV.$$

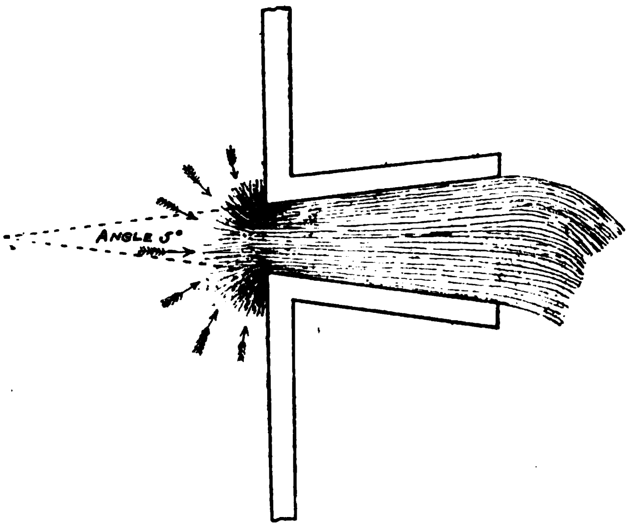


FIG. 9.

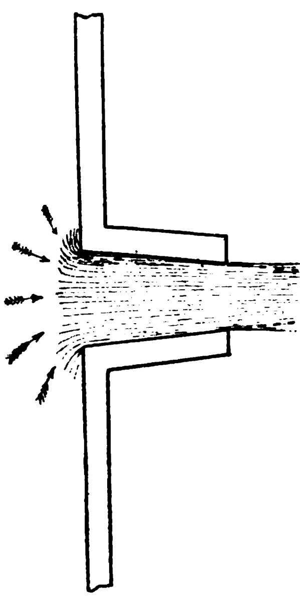


FIG. 10.

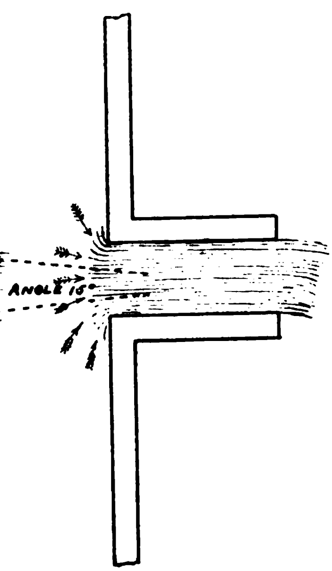


FIG. 11.

Where the discharge is through orifices in vertical partitions, the openings being furnished with short tubes (see Fig. 11), the co-efficient becomes about 80 per cent. Here,

$$D = .80\ AV.$$

If the short tube projects a little inside the vertical partition, as in Fig. 12, the co-efficient is diminished by about 1-8 part, becoming about .71. Here,

$$D = .71\ AV.$$

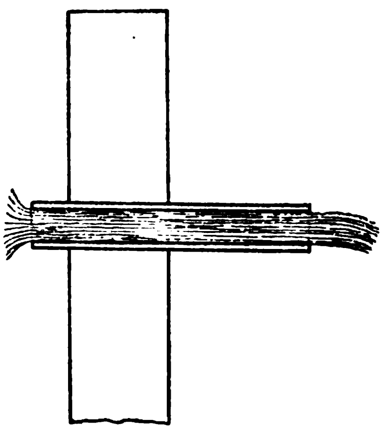


FIG 12.

In orifices in thin vertical partitions (see Fig. 13), where the water flows out freely into air, the percentage will be about 62. Here,

$$D = .62\ AV.$$

Where the contraction is incomplete, either the sides or bottom, or in fact any part of the perimeter of the orifice being flush with the sides, bottom, etc., of the containing reservoir, the co-efficients will increase from .62 up to .80 about as follows:

For complete contraction co-efficient = .62 or D = .62 AV.
With contraction on $\frac{3}{4}$ the perimeter, .64 or D = .64 AV.
With contraction on $\frac{1}{2}$ the perimeter, .67 or D = .67 AV.
With contraction on $\frac{1}{4}$ the perimeter, .70 or D = .70 AV.
With no contraction on the perimeter, .80 or D = .80 AV.

Where the opening is provided with an indefinitely long horizontal trough, the discharge will be decreased slightly; for very small heads the decrease will be considerable, perhaps 20 per cent., but if the head is at least two times the height of the opening, the diminution from the theoretical head will be hardly appreciable, and may then be disregarded.

In cases where the orifice discharges under water the coefficient should be diminished by 2 per cent., becoming .60 instead of .62, etc. In this case, however, in computing the velocity the head must be taken as equal to the difference between the levels of the water within and without the containing reservoir measured vertically.

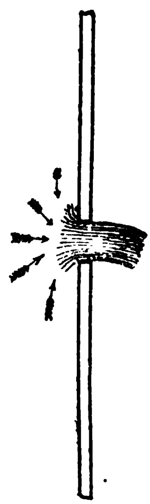


FIG. 13.

DISCHARGE FROM RESERVOIRS.

Mention has been made of an exception that would be considered to the rule that only cases would be taken into account where the water level remains constant. This is the case of a reservoir from which the water is being drawn off, the surface of the water becoming continually lower. Here the depth may be considered as being divided into a number of parts and the center of each part or section of the depth may be considered as the constant depth until all of the water for that portion of the depth has been drawn off. The case thus resolves itself into a number of separate cases, each of which is to be treated as already described.

Supposing, for example, that we have a reservoir, twelve feet of which may be drawn off; this twelve feet may be considered as divided into six parts from 12 to 10, with an average head of eleven feet; from 8 to 10, with an average head of nine, etc., etc., until all the water has been drawn off.

The cases and formulæ given cover more ordinary measurements necessary. It must be understood, of course, that it is not expected that exact results will be obtained, but there is no reason why, with care, results within 5 per cent. of the theoretical amounts may not be obtained.

AN OUTLINE OF THE IRRIGATION LAWS OF COLORADO.

In the following outline it is endeavored to give a few of the essential features of the irrigation laws that may aid people who contemplate the taking up of land and acquiring water rights in this state.

The basic principle underlying the Colorado irrigation law is good, viz.: That all the water originally belongs to the public and can only be acquired by individuals or corporations through application to beneficial use and only so long as that beneficial use continues. But the law which permits the segregations of the water from the land and the right of transfer is faulty. This feature has encouraged speculation and consequently stimulated development for a time, but it has also caused litigation.

As the country grows older, however, and the water supply is exhausted, the necessity for more stable conditions becomes apparent. This necessity tends to draw the different interests under one drainage system more closely together. People see the necessity of working in harmony instead of fighting each other. The money spent in litigation might well be spent in perfecting the irrigating systems. There has already been considerable advancement in this direction.

Heretofore the tendency has been to continually tinker at the laws and try to improve them by patchwork. The effort should, and will in the future, be towards making the laws and the administration machinery as simple as possible.

MANNER OF ACQUIRING TITLE TO WATER.

Water public property; to be appropriated by any person who will put it to beneficial use.

Section 5 of Constitution: The water of every natural stream, not heretofore appropriated, within the state of Colorado, is hereby declared to be the property of the public, and

the same is dedicated to the use of the people of the state, subject to appropriation as hereafter provided.

Section 6. The right to divert unappropriated water of any natural stream for beneficial uses shall never be denied. Priority of appropriation shall give the better right as between those using water for the same purpose.

Water can not be taken for domestic purposes, however, from prior appropriators for irrigation and manufacturing purposes without compensation.

REVISED STATUTES.

All unused waters subject to appropriation.

All waste, seepage or spring waters may be acquired and utilized under the same laws relating to priority of right as the waters of running streams.

The same laws also govern the storage of surplus or flood waters in reservoirs.

No flood waters are permitted to be stored when they are needed by ditches having prior appropriations for direct irrigation.

Reservoirs may be constructed on natural streams, but provision must be made for the natural flow of the stream to pass unobstructed through the same. Persons constructing such reservoirs must provide the necessary rating flumes or weirs for measuring the flow into and out of them.

The first act in securing an appropriation is to begin work of construction. A survey is held to be a part of work of construction. Within ninety days from commencement of work a plat and sworn statement giving line of ditch or high-water line of reservoir, source of supply, amount of water claimed, etc.; must be filed in the office of the State Engineer and also with the county clerk of the county in which the headgate of such ditch is situated. Instructions for making such statement can be had on application to the State Engineer's office.

The essential element of a valid appropriation is the application of the water to a beneficial use. Due diligence should be shown in prosecuting the work of construction of any ditch or reservoir after it is once begun, and the same shall be completed within three years from time of commencement.

After a ditch or reservoir is completed and water actually put to use, the final acquisition of title, or "proving

up" is had by an adjudication in the District Court. This is a lengthy proceeding which can not be explained in this short paper.

Attention is called to the importance of securing the title to water. The following is quoted from the Tenth Biennial Report of the State Engineer, under the head of "Adjudication of Rights": "Much carelessness is manifested in this direction, especially in the mountain districts, where the water supply is considered abundant. * * * The time is not far distant when every available drop of water will be appropriated. Many delay an adjudication on account of expense. If it were to perfect title to their lands no such excuse would present itself. To quote from the report of Superintendent Armstrong, 'the longer the sitting of a referee's court is delayed the more expensive it will be and the more difficult it will be to prove priorities.'"

ENLARGEMENT OF DITCHES.

Where water can not be as conveniently carried in some other channel the right to enlarge an existing ditch is given, but the parties making the enlargement must pay a reasonable share of the cost of said ditch.

A natural stream may be used as a conduit, especially for carrying water from a reservoir to lands desired to be watered, due allowance being made for loss by evaporation and seepage, said loss to be determined by the State Engineer.

TRANSFERS.

If the vested rights of other water users are not injuriously affected, the right to change the point of diversion and the place and character of the use is given. Parties desiring to make such change must apply to the District Court from which the original decree issued and procure a decree of transfer.

ABANDONMENT.

A failure to use an appropriation for a considerable period may be taken as an evidence of intention to abandon. But what constitutes abandonment has not been settled; and, in fact, no definite time can be fixed, and the question can only be settled by the circumstances of each individual case. However, as land and water become more valuable, but few controversies are likely to arise over the question

of abandonment, as each appropriator will be interested in seeing that his rights are maintained.

THE ADMINISTRATIVE DEPARTMENT.

The administration of the laws is vested in the State Engineer, the superintendents of irrigation of the six divisions, and the water commissioners of the sixty-nine water districts. The duties of these various officers are pretty well known and need not be explained. Water users who have occasion to take appeals from the commissioner to the superintendent and from the superintendent to the State Engineer, should require the commissioner and superintendent to put their decisions in writing, which must be filed with the superior officer, together with the appeals.

The water commissioner is the most important of all the officers, as he has direct charge of the distribution of the water, and is working every day directly among the people. It is a matter of business, then, that the people of every district should be willing to pay a living salary, and then see that men be appointed to the position who are competent to earn it. There will then be a stimulus for young men to prepare themselves with the necessary technical training to fill the position. We think there is a rapidly growing sentiment among the people in this direction.

In view of the importance of this position it may be well to recite here a few of the principal duties of the commissioner. It is his duty, after being called upon to distribute water, to devote his entire time so long as the necessities of irrigation require; to be actively employed on the line of the stream, directing the putting in of headgates, wastegates, keeping the streams clear of dams, or other obstructions, and such other duties as pertain to a guard of the public streams of his district; and for a wilful neglect of duty shall be liable to $50.00 fine, with cost of suit.

The water commissioner has no supervision over the distribution of water after it leaves the stream, except to see that it is not wrongfully or wastefully used. Act of 1895, page 197, provides that at the request of one or more ditches in his district, the water commissioner shall make, or cause to be made, an examination of all the ditches within his district, to see what use is being made of the water, and if he discovers that any water is being wastefully, extravagantly or wrongfully used it is his duty to immediately shut off so much as in his opinion is so being used. He has author-

ity to appoint not to exceed two deputies to make such examinations. This law puts considerable discretionary power in the hands of the commissioners, and much more than many of them care to assume. Yet it is of great importance that such power be exercised at times. It is well known that there is a great waste of water in many instances, especially by the oldest appropriators. This habit was acquired principally when water was plenty, and no harm was done except to the users themselves in the damage to their lands, and such habit, once acquired, is hard to break.

DUTIES OF DITCH OWNERS.

Owners of ditches must maintain embankments, so that the waters of such ditch may not flood or damage the premises of others, or may not flood highways, and are liable to damages caused by any such flood. Parties constructing ditches must bridge any highways that may be crossed by such ditch.

HEADGATES AND MEASURING FLUMES.

Owners must keep headgates in proper repair and provide the necessary measuring flumes or weirs, together with embankments of sufficient height and strength to control the waters. Upon failure to comply with the above provision, the State Engineer or superintendent of irrigation is empowered, upon ten days' previous notice, in writing, duly served upon the owners or agents or employes, to refuse to deliver water to such ditches until such headgate and rating flumes, or other measuring devices, shall have been constructed.

While this law may seem somewhat drastic, it was necessary to do something to stir up ditch owners to provide better means of controlling the water, or better means of measuring the same. They can not expect the commissioners to give them good service unless they provide the necessary means for delivering the water to them. Much has been done in this direction within the last year, but much yet remains to be done, especially in the mountain districts.

CHAPTER IX.

SPECIAL REPORT ON EASTERN, WESTERN AND NORTH-WESTERN COLORADO.

A. J. McCune,

State Engineer, Denver, Colorado.

Dear Sir—During the last two years there have been made, in connection with other work, three trips in different parts of the state—the northeastern part, the Grand Mesa and country around Delta, and a trip to Wolcott, north to Steamboat Springs, thence to Craig, and so back to Rifle.

EASTERN COLORADO.

The principal trips made in the north and eastern part of the state were made in connection with the Morgan, Washington, Yuma county road.

The character of the country is necessarily familiar to almost every one in Colorado, as it is traversed by the railroads connecting Colorado with the Eastern states—a rolling prairie country traversed by streams which, for the most part, are dry the greater part of the year. In its natural state, the soil supports a good growth of grass, and made the vast herds of buffalo of the early days possible and later made our cattle kings.

The Platte river and the Republican are the two principal streams, and it is along them that almost all the land farmed is located.

On the Platte, eastward from Greeley to the state line, there is a strip of land from one to ten miles in width lying under ditches, and which is cultivated and irrigated. The most notable section is, perhaps, in the vicinity of Fort Morgan and Brush. Here the land is unsurpassed in quality,

being a sandy loam, where the abundance of cactus testifies to its richness.

For some years there has been in contemplation and under construction a large high-line canal which will cover land on the south side of the river and west of the town of Fort Morgan.

The ditch is known as the Bijou, and will be supplied from the Platte river during high water, at which time reservoirs will also be filled for use during the low stage of water in the river.

The measurements and records collected by this office of the seepage flow in the Platte river indicate that there will be sufficient water for the ditch.

The people of the community devote their time more to farming than to stock-raising. During the winter, however, a great many cattle and sheep are fed.

On the north side of the river, also, is an enterprise of considerable magnitude, in which stored water will be mainly relied upon.

The proposals for reservoirs, as will be seen in the summary of filings, indicate considerable activity, and it is reasonable to expect that all the water on the Platte drainage, both flood and seepage, will be made use of in a very few years, if indeed that condition is not already reached with the reservoirs now under construction.

Along the valley of the Platte to Sterling considerable wild hay is raised, as well as alfalfa, and as we proceed eastward the cattle interests become more and more important.

Sterling is a most prosperous community, due, I believe, to her cattle interests, as the surrounding country is one vast prairie.

In the vicinity of Sterling is the much-talked-of Pawnee Reservoir now being investigated by the government. The enterprise has been investigated before by different parties, who have abandoned it as not feasible, or, at least, not justifying the investment of private capital.

The difficulties to be overcome are considerable. The ditch is nearly 100 miles long, and through sand hills for a considerable distance. The matter of water supply is, perhaps, the most vital to the enterprise. With a year like the one just past, and with the completion of reservoirs now under construction, it is a question, especially in view of the distance the water must be carried, whether the amount available will justify the building of the ditch and reservoir.

The report of the government engineer will be made probably early in the year and, in view of an early and definite report, it is not advisable to comment further at this time.

From Sterling to the state line the area of irrigated lands diminishes, and at Julesburg is very narrow.

Between the Platte and the Republican is a fine prairie country, somewhat broken, and in places considerable areas of sand, which drifts with the heavy spring winds, forming sand dunes, trending in a northeasterly and southwesterly direction.

Wherever the sod has been broken and the surface plowed the wind has blown deep depressions, and it is often possible to distinguish accurately the twenty or forty acres plowed by the homesteader in taking up the land.

Between the Platte and the Republican is the great "Rain Belt," to which, some years ago, there was a perfect stampede. Thousands of claims were filed upon, fenced, houses built, trees planted and crops put in. A few years of unusual rainfall had led to the belief that the irrigation of land along the streams had changed the climate to such an extent that eastern Colorado and western Nebraska had become humid, and that crops could be raised without irrigation. A few years, however, of normal or subnormal rainfall served to effectually disprove this very attractive theory, and now the country is scarcely more populous than before. The people were literally starved out, their claims abandoned and they scattered, seeking locations where irrigation was possible, or returning to their Eastern homes. What people remained, however, have, with their cattle and the free range, become prosperous, and many even wealthy.

Over a considerable territory it appears that the range is now overstocked, the native grasses are being stamped out and destroyed and will not now support nearly as many animals as formerly. This condition has been intensified during the last two years by the extremely dry seasons and lack of rainfall.

The number of cattle should, in some manner, be limited and the grass allowed to reseed itself and to spread over the bare spots.

There is now considerable Russian thistle growing wherever the sod is thin or broken. This is cut while tender, and makes a fair feed for roughing cattle through. It is said that even the old dry bunches are eaten by the cattle in the spring whenever the rains or snows soften up the spines.

Along the branches of the Republican and along the Arickaree are narrow strips of farm land, irrigated from these streams. The product is largely second bottom hay, though considerable alfalfa is raised, and, on the higher lands, wheat forms a large part of the year's crop. From the town of Wray considerable wheat, flour and hay are shipped, and it is in every way an attractive, busy, business-like town. Wray is quite a cattle center, and from it many cattle are annually shipped to the river markets. The water supply is quite good, and most of the lands under ditch have sufficient water.

In a considerable part of the territory there was apparently an overstocking of the range. The grass was being eaten out by the cattle and sheep to such an extent as to be almost entirely destroyed. Large herds were annually shipped into the state to enjoy the free summer range, free both of rent and taxes, and again shipped out in the fall. The grass was hardly allowed to start growing, and, when winter came, had been grazed so closely that no winter feed remained for the home cattle, to say nothing of the destruction of the range, permanently. Something surely should be done to preserve the ranges, either by leasing or some other method. The range properly preserved is one of the greatest assets and sources of wealth in the state. On account of the greed of some and the irresponsibility of all, it should not be allowed to suffer.

WESTERN COLORADO.

In June, 1902, I proceeded to Delta for the purpose of making an examination of the reservoir systems of the Grand mesa, viewing the North Fork country, which the railroad had just entered, and settling some disputes on streams south of Crawford and tributary to the Gunnison river.

From Delta, with the water commissioner, Mr. Henry Payne, I drove to the top of Grand mesa, passing at first through an extremely desolate, dry country, traversed by deep arroyas—a most uninviting prospect, but where recently numberless oil claims had been taken up.

Some ten miles from Delta we came into a section where orchards and alfalfa had created a prosperous, thriving community. The soil here is mostly the fine, white, heavy sagebrush-covered variety found on the western slope. It contains considerable gypsum and some alkali, though not enough of the latter to do damage to the growing plants. It is a rich soil, strong in mineral plant food, and is formed from the decomposition of the great shale deposits. The cedar

GUNNISON RIVER CANON, NEAR HEAD OF GUNNISON TUNNEL.

ridges have been taken up wherever water could be obtained. One farm of note is that of Mr. Henry Coler, at which we were most hospitably entertained; there are several thousand acres in the place, mostly in alfalfa. It is remarkable for the completeness of its furnishings and the orderly manner in which it is run. The most modern machinery in abundance, good buildings, a comprehensive system of irrigation, and a perfect organization of the working force make it a model place. The product is mostly consumed by feeding cattle in the winter.

On the Grand mesa our first stop was made at the Alexander lakes, where, a few years ago, a most deplorable shooting took place, with the subsequent burning of the hotel and fish hatcheries.

There are more than a score of reservoirs here, covering from five to one hundred and sixty acres. Most of them are natural lakes, with a small dam across the outlet, with valves to control the flow. In many of these lakes it was observed that where the water was raised above the natural high-water line that considerable loss occurred, probably the water found its way through the more or less porous soil surrounding the lakes.

It was noticed also that the flow in the streams was well maintained and even considerably increased since the building of the reservoirs, showing conclusively that the seepage soon found its way to the water courses.

These reservoirs have made possible the irrigation of the farms and country referred to above, and, though small, are of the greatest value.

All the streams of the Grand mesa have these small lakes at their heads and it is estimated that the number is considerable in excess of 100.

As a resort it is ideal, trout abounding in all the streams and lakes, and which furnish to the state and national fish hatcheries millions of spawn every year.

From the Grand mesa we drove to Hotchkiss and saw some of the finest orchards I have ever seen. The peach orchards especially were remarkable for their size, the amount of their product and the quality of the fruit. The North Fork country has been given an unprecedented prosperity by the advent of the new railroad and land in orchard is held at $500 per acre. From Hotchkiss we drove south to Crystal creek past prosperous farms and thriving communities. The creek at the point that was crossed carried thirty-eight feet of water. From Crystal creek southeasterly to Sapinero we

passed through a most excellent cattle range, the bunch grass growing luxuriantly and numerous springs furnishing an abundance of water; while there are a great many cattle on the range, it did not appear to be overstocked. Though removed far from the usual route of travel and somewhat undeveloped, taken all in all the country passed through on this trip would be hard to equal even in Colorado.

NORTHWESTERN COLORADO.

On October 9 I started on a trip through Garfield, Rio Blanco and Routt counties, the especial objects being to visit the country between Wolcott and Steamboat Springs, which district had never been visited by a representative from this office. On October 10 we left Wolcott, having secured a team at that place. We crossed the Grand river at the state bridge near the mouth of the Piney, the gaging showed that the river at that point was carrying 488 feet. This was said to be the lowest stage known. The Piney was carrying something over 100 feet. McCoys, where we spent the night, is an excellent place to stop. Here we measured Rock creek, which was at about its lowest stage. We found the flow to be ten and one-half cubic feet. We crossed Egeria creek and estimated that there were four cubic feet in it, some of which was said to come from a reservoir at the head of the creek. At this point we encountered a very heavy snow storm which lasted nearly two days, sometimes driven by the wind reaching almost the dignity of a blizzard. Several small streams were crossed before reaching Steamboat Springs, none of which, however, carried to exceed five feet of water.

On October 13 we reached Steamboat Springs and measured the river at the bridge just west of town. We found at that point 112 feet; the channel is very good and this point could be made a good, permanent gaging station. From Steamboat Springs we proceeded westerly on the Hahn's peak road, as far as Big creek, which was flowing an estimated amount of six feet. From this point we returned to Trull and measured Elk river, which was carrying 147 cubic feet. We spent the night at a farm some six miles west of Trull and the next day drove to Craig. On the way we measured the river at Hamilton and found 235 cubic feet; considerable water was running in the ditches in the vicinity, the amount being probably 100 cubic feet. Elkhead creek was crossed and was carrying about ten cubic feet of water. Fortification creek, in the vicinity of Craig, had little or no water, as it was still being used for the ditches. At Craig we

rested one day, our team being worn out, pulling through the heavy mud, occasioned by the recent snow. The river was measured at Craig and 243 cubic feet at a gage height of 2.3 was found. From Craig we proceeded to Hamilton, where we spent the night. Measured Williams Fork at that point, which was flowing 47 cubic feet.

On the 17th we reached Meeker, where the White river was measured and found to contain 342 cubic feet at the gage height of 2.55. From Meeker we proceeded along the stage road to Rifle, which ended our driving.

The country from Steamboat Springs through Craig and Meeker to Rifle has been well described by Mr. A. L. Fellows in the Ninth Biennial Report and needs no repetition here.

The country from Wolcott to McCoy, while very picturesque and interesting geologically, is rather barren and uninviting. On the Piney and the Sheep Horn or Quaking Aspen creeks there are many small mountain farms commanding a large grazing country.

From McCoy to Toponas is a good cattle country and I understand that on the flat tops there is excellent pasturage.

From Toponas to Yampa there are numerous good farms where a good deal of wild hay is cut.

From Yampa to Steamboat Springs there is almost one continuous farm, the meadows are fairly broad and produce good crops of timothy and wild hay. This season timothy was worth $10 or more in the stack. In the vicinity of Steamboat Springs some alfalfa was raised and this was said to be worth in excess of $6 per ton. Steamboat Springs is a most attractive place. There are in its immediate vicinity numerous sulphur springs, several of which have a temperature of 103 to 150 Fahrenheit. The town is quite a resort for invalids and sportsmen and the advent of the Moffat railway is eagerly anticipated.

From Steamboat Springs to Craig there is a broad valley of bottom land raising timothy and wild hay. The product, however, is scarcely sufficient for the large demand, many cattle, which have their summer range in the valleys to the north and south, being wintered along the river. In the vicinity of Craig considerable alfalfa is raised and some grain. During the season of 1902 the weather was quite cold, the hay crop short and much of the grain did not fully mature. On the streams tributary to the Bear or Yampa river there is considerable land in small areas more or less scattered which can be developed into good farms, and I antici-

pate on account of the grand range and the large number of cattle raised that there will always be a good demand for all kinds of hay for winter use. I did not visit the country along Fortification or Elkhead creeks. I understand, however, there is a grand area of fine farming land in that region and that the Elk river, which I found to contain more water than any stream tributary to the Bear, could be diverted to irrigate this land.

I would suggest that the state make such investigation of this country as is necessary to be able to present to the government such facts as will induce them to make a careful investigation of the enterprise.

For almost the entire distance traveled we saw deposits of coal, some of which were being worked by the settlers for their own use and others which had not been touched. The whole country traversed seems to be one vast coal deposit. Especially noticeable was the very fine quality of blacksmithing coal in the vicinity of Poole postoffice. It is to be regretted that our time was so limited that we could not penetrate into the country tributary to the route traveled.

Along the route traveled the country is fairly well settled and almost all taken up. In the more remote regions, however, there is much excellent land still subject to entry, and which can be farmed by the construction of inexpensive ditches, but which should generally be supplemented by reservoirs. Those propositions which are easiest and which require a ditch only have been pretty generally taken up, and future development will depend somewhat on the possibility of the settler finding a small inexpensive reservoir site.

While there is considerable mineral in Routt county, great coal deposits and much natural wealth, I believe that the cattle interests will always be predominant, and it is from this enterprise that I look to see the greatest prosperity to the county. I regret to say, however, that in many places the range is now overstocked.

Yours truly

JOHN E. FIELD.

CHAPTER X.

STREAM GAGINGS.

Denver, Colorado, November 15, 1902.

HON. A. J. MCCUNE,
State Engineer of the State of Colorado.

Dear Sir—I take pleasure in handing you herewith, in accordance with your request, and with the consent of Mr. F. H. Newell, Chief Engineer of the Division of Hydrography of the United States Geological Survey, all available data obtained by myself, as Resident Hydrographer of the said survey in the state of Colorado, during the years 1901 and 1902, and also all data connected with the discharge of streams during those years which have been furnished me by co-operating companies and individuals.

A brief review of the system of co-operation between the Division of Hydrography of the United States Geological Survey and your own office may not be out of place at this point. It has been the policy of this division, throughout a number of years, to secure all available information concerning the discharge of the various streams of the United States, and particularly of its arid territory, in which a thorough knowledge of the conditions bearing upon precipitation, run-off, discharge of streams, and like matters, would be of the greatest possible benefit in determining the amount of lands that could be irrigated by means of an enlightened system of irrigation. It was further hoped that such information might be of value in determining localities that might be benefited by government aid in irrigation. These interests being to a great extent identical with those of the State Engineer's office in Colorado, the laws of which state direct that the State Engineer shall make stream gagings and obtain a knowledge of the discharge of the various

streams of the state, and also that he shall compile data concerning the precipitation throughout the state, it has been obviously advantageous that a system of co-operation between state and government in these lines should be devised and practiced. For a number of years, therefore, commencing to some slight extent as far back as the year 1884, but re-established upon a much better and more thoroughly co-operative basis in the year 1895, such a system has been carried on, becoming more firmly compacted and of greater value to each party to the plan with each succeeding year.

On the part of the division of hydrography, therefore, I take this opportunity of thanking you for the courtesy extended by you and all your subordinates in furnishing to us the use of your office and such assistance as you have been able to render throughout the years 1901 and 1902, and to express my belief that the results obtained have been mutually of the greatest advantage. Thanks are due also to a number of corporations and individuals throughout the state, notably to the Denver & Rio Grande railroad, the Colorado Springs & Cripple Creek District Railway Company, the Colorado & Southern Railway Company; the Chicago, Burlington & Quincy Railway Company, the Union Pacific Railroad Company, and the Atchison, Topeka & Santa Fe Railway Company. Also, to the Great Plains Water Company, and many other corporations, and to the water commissioners and individuals interested in the development of irrigation throughout the state generally, without whose assistance it would have been impossible for so much to have been accomplished.

It has always been the policy of the department which I have the honor of representing, so far as possible, to make public the data obtained concerning the discharge of streams as generally and at as early a date as has been practicable. On this account, information has been furnished to superintendents of irrigation divisions, water commissioners, newspapers, corporations, and to parties generally who have expressed an interest in or desire to receive such information.

In the tables which are furnished herewith, the same plan of arrangement has been adopted as in the last report of the State Engineer, submitted by yourself two years since. Various modifications as to tables have, however, been made which should receive passing notice. Owing to the fact that in your last report you published data furnished by me covering all preceding years to the year 1900, inclusive, and owing to the further fact that the United States Geolog-

ical Survey has published this data in the form of Water Supply and Irrigation Paper No. 74, a supply of which is to be furnished to your office, and a copy of which may be obtained upon application by any one desiring it, it has seemed unnecessary that data for years prior to 1901 should be given in this compilation. The discharge is shown, therefore, for the years 1901 and 1902 alone, and the same form of table is given as is printed in the reports of the Hydrographic Division of the United States Geological Survey, it being believed that this form is of greater value to the general public than the form previously presented in the State Engineer's reports. It has seemed unnecessary, also, that descriptions of streams and gaging stations should be published at this time, as this information was furnished in your last report, and the stations will, therefore, be described only where important changes have been made, or where new stations have been operated, the information being given in foot notes below the tables. This office being in possession of all details, information not furnished in these tables may readily be ascertained at any time by those sufficiently interested.

———— stations have been maintained during either the whole or parts of the past two years, the data for which stations will be furnished in separate tables. Two lists of stations are given, following the plan adopted in your last biennial report—the first giving the locations of stations in their order, referring to irrigation division and locality upon the stream, commencing at the head of the division and proceeding generally down stream, and the second an alphabetical list of streams measured, with location of station. The tables follow, arranged in the order given in the first list:

IRRIGATION DIVISION NO. I,

OR, THE SOUTH PLATTE IRRIGATION DIVISION.

Cheesman station, on south fork of South Platte river.
South Platte station, on South Platte river.
Denver station, on South Platte river.
Kersey station, on South Platte river.
Julesburg station, on South Platte river.
Morrison station, on Bear creek.
Forks Creek station, on Clear creek.
Marshall station, on South Boulder creek.
Boulder station, on Boulder creek.

Lyons station, on St. Vrain creek.
Arkins station, on Big Thompson creek.
Fort Collins station, on Cache a la Poudre river.

IRRIGATION DIVISION NO. II,

OR, THE ARKANSAS IRRIGATION DIVISION.

Twin Lakes station, on Lake creek.
Salida station, on Arkansas river.
Canon City station, on Arkansas river.
Pueblo station, on Arkansas river.
Nepesta station, on Arkansas river.
Rocky Ford station, on Arkansas river.
Prowers station, on Arkansas river.
Lamar station, on Arkansas river.

IRRIGATION DIVISION NO. III,

OR, THE RIO GRANDE IRRIGATION DIVISION.

Del Norte station, on Rio Grande.
Colorado State Line station, on Rio Grande.

IRRIGATION DIVISION NO. IV,

OR, THE SAN JUAN IRRIGATION DIVISION.

Ignacio station, on Los Pinos river.
Durango station, on Florida river.
Durango station, on Animas river.
Mancos station, on Mancos river.

IRRIGATION DIVISION NO. V.

OR, THE GRAND IRRIGATION DIVISION.

Glenwood Springs station, on Grand river.
Palisades station, on Grand river.
Iola station, on Gunnison river.
Whitewater station, on Gunnison river.
Dolores station, on Dolores river.

IRRIGATION DIVISION NO. VI,

OR, THE GREEN IRRIGATION DIVISION.

Craig station, on Yampa river.
Hamilton station, on Williams river.
Meeker station, on White river.

STREAMS ON WHICH STATIONS ARE LOCATED.

Animas river, at Durango.
Arkansas river, at Canon City.
Arkansas river, at Lamar.
Arkansas river, at Nepesta.
Arkansas river, at Prowers.
Arkansas river, at Pueblo.
Arkansas river, at Rocky Ford.
Arkansas river, at Salida.
Bear creek, at Morrison.
Big Thompson creek, at Arkins.
Boulder creek, at Boulder.
Cache a la Poudre river, at Fort Collins.
Clear creek, at Forkscreek.
Dolores river, at Dolores.
Florida river, at Stewart's ranch, near Durango.
Grand river, at Glenwood Springs.
Grand river, at Palisades.
Gunnison river, at Iola.
Gunnison river, at Whitewater.
Lake creek, at Twin Lakes.
Los Pinos river, at Ignacio.
Mancos river, at Mancos.
Rio Grande, at Colorado State Line.
Rio Grande, at Del Norte.
South Boulder creek, at Marshall.
South fork of South Platte river, at Cheesman lake.
South Platte river, at Denver.
South Platte river, at Julesburg.
South Platte river, at Kersey.
South Platte river, at South Platte.
St. Vrain river, at Lyons.
White river, at Meeker.
Williams river, at Hamilton.
Yampa river, at Craig.

SOUTH PLATTE IRRIGATION DIVISION.*

CHEESMAN STATION, ON SOUTH FORK OF SOUTH PLATTE RIVER.**

Drainage area, 1,677 square miles.

ESTIMATED DISCHARGE.

Month	Discharge in Second-Feet			Total in Acre-Feet	Run-off	
	Maximum	Minimum	Mean		Second-Feet per Square Mile	Depth in Inches
1901						
January	16	13	14	861	.01	.01
February	19	13	15	833	.01	.01
March	95	17	67	4,120	.04	.04
April	346	67	198	11,782	.12	.13
May	557	105	341	20,967	.20	.23
June	600	70	260	15,471	.15	.17
July	195	30	92	5,657	.05	.06
August	753	165	342	21,029	.20	.23
September	295	100	166	9,878	.10	.11
October	134	65	99	6,087	.06	.07
November	134	85	104	6,188	.06	.09
December	325	35	88	5,411	.05	.06
Totals	753	13	149	108,284	.09	1.21

*See page 246, Tenth Biennial Report.

**See page 248, Tenth Biennial Report. The discharge given is for Goose Creek and the South Fork of the South Platte river combined, below the Cheesman dam. Data furnished by The Denver Union Water Company.

INFLOW TO LAKE CHEESMAN FROM THE SOUTH FORK OF THE SOUTH PLATTE RIVER, AND FROM GOOSE CREEK,

September 2 to October 16, 1902.

The following results are from measurements taken at temporary weirs established on the South Fork and Goose creek above where they empty into Lake Cheesman.

The measurements cover the period during which the flow was a minimum.

Date	South Fork Cubic Feet per Second	Goose Creek Cubic Feet per Second	Total Cubic Feet per Second
September 2, 1902	1.89	....	....
September 3, 1902	3.00	....	....
September 4, 1902	2.46	3.35	5.81
September 6, 1902	1.29	2.71	4.00
September 11, 1902	.42	2.86	3.28
September 13, 1902	.37	2.86	3.23
September 18, 1902	.28	3.22	3.50
September 20, 1902	.10	3.52	3.62
September 22, 1902	3.26	9.52	12.78
September 24, 1902	4.50	8.86	13.36
September 26, 1902	1.71	9.10	10.81
October 5, 1902	3.00	9.93	12.93
October 13, 1902	5.00	10.86	15.86
October 16, 1902	6.50	10.86	17.36

Note—The only available data compiled for the year 1902, up to this date (December 1st), are given above, as furnished by The Denver Union Water Company. The above results correspond to the natural flow of the two streams below Cheesman lake for the corresponding dates.

SOUTH PLATTE STATION, ON SOUTH PLATTE RIVER.*

Drainage area, 2,612 square miles.
Observer, John B. Swan.

LIST OF DISCHARGE MEASUREMENTS.

Date	Hydrographer	Gage Height	Discharge	Remarks
April 30, 1901	John E. Field	6.70	830	
May 11, 1901	A. L. Fellows	5.67	270	
June 28, 1901	John E. Field	5.50	192	
Aug. 5, 1901	A. J. McCune		293	
Aug. 7, 1901	John E. Field	6.30	676	
Mar. 28, 1902	John E. Field	1.85	145	
May 2, 1902	John E. Field	2.00	208	
June 13, 1902	S. G. Lees	1.87	167	
July 17, 1902	S. G. Lees	1.00	53	
July 17, 1902	S. G. Lees	1.04	60	
Aug. 12, 1902	S. G. Lees	1.00	53	
Aug. 25, 1902	J. E. Field	1.55	122	
Sept. 7, 1902	M. C. Hinderlider	1.20	69	
Sept. 8, 1902	J. E. Field	1.20	69	
Sept. 13, 1902	M. C. Hinderlider	1.25	79	
Sept. 23, 1902	M. C. Hinderlider	1.45	108	
Oct. 17, 1902	S. G. Lees	1.20	60	
Oct. 27, 1902	R. W. Hawley	1.18	57	

*This station was established March 28, 1902, by John E. Field, at the wagon bridge below the forks of the river.

ESTIMATED DISCHARGE.

Month	Discharge in Second-Feet			Total in Acre-Feet	Run-off	
	Maximum	Minimum	Mean		Second-Feet per Square Mile	Depth in Inches
1901						
April	593	119	261	15,531	.10	.11
May	211	63	142	8,731	.05	.06
June	207	60	88	5,236	.03	.03
July	61	55	58	3,566	.02	.02
August	61	55	57	3,505	.02	.02
September	127	57	77	4,582	.03	.03
October	86	45	61	3,751	.02	.02
November	57	40	50	(1) 1,091	.02	(1) .01

Note—The average discharges of the river at this point for the period, January 14, 1902, to January 28, 1902, inclusive, as furnished by L. B. Curtis, was 69.9 sec. feet.

(1) For eleven days.

DENVER STATION, ON SOUTH PLATTE RIVER.*

Drainage area, 3,840 square miles.
Observer, Frank Kelly.

LIST OF DISCHARGE MEASUREMENTS.

Date	Hydrographer	Gage Height	Discharge	Remarks
April 30, 1901	John E. Field	6.70	830	
May 11, 1901	A. L. Fellows	5.67	270	
June 28, 1901	John E. Field	5.50	192	
Aug. 7, 1901	John E. Field	6.30	676	
April 1, 1902	John E. Field	1.10	107	
May 15, 1902	John E. Field	1.65	241	
May 29, 1902	John E. Field	2.22	557	
June 10, 1902	S. G. Lees	1.00	74	
June 11, 1902	S. G. Lees	.98	62	
June 12, 1902	S. G. Lees	1.05	68	
June 18, 1902	S. G. Lees	1.85	163	
June 16, 1902	S. G. Lees	1.00	63	
July 16, 1902	S. G. Lees	1.09	18	Channel changed since last measurement on June 16, 1902
July 22, 1902	S. G. Lees	1.13	32	
Sept. 9, 1902	M. C. Hinderlider	1.10	22	
Sept. 12, 1902	M. C. Hinderlider	1.00	16	
Oct. 14, 1902	M. C. Hinderlider	1.30	63	
Oct. 28, 1902	R. W. Hawley	1.19	48	
Oct. 29, 1902	R. W. Hawley	1.12	42	

*See page 256, Tenth Biennial Report. New gage rod set on May 15, 1901, by John E. Field, deputy state engineer. The gage readings for the irrigating season of 1902 were worthless.

ESTIMATED DISCHARGE.

Month	Discharge in Second-Feet			Total in Acre-Feet	Run-off	
	Maximum	Minimum	Mean		Second-Feet per Square Mile	Depth in Inches
1901						
January	242	186	212	13.035	.06	.07
February	242	186	217	12.050	.06	.06
March	306	213	241	14.818	.06	.07
April	1.121	242	516	30.704	.13	.14
May	1,026	113	553	34,003	.14	.16
June	1,386	113	715	42,545	.19	.21
July	575	17	249	15,310	.07	.08
August	618	242	365	22,443	.10	.11
September	422	51	216	12.853	.06	.07
October	213	17	92	5,657	.02	.02
November	136	17	72	4 284	.02	.02
December	341	113	234	14.388	.06	.07
The year	1.386	17	307	222,090	.08	1.08
1902						
April 1-19	96	53	74	(1) 2,789	(1) .02	.01
October	90	56	71	(2) 3,098	(2) .02	.02
November 1-15	56	13	32	(3) 952	(3) .01	.004

(1) For nineteen days.
(2) For twenty-two days.
(3) For fifteen days.

KERSEY STATION, ON SOUTH PLATTE RIVER.*

Drainage area, 9,470 square miles.
Observer, Edward K. Plumb.

LIST OF DISCHARGE MEASUREMENTS.

Date	Hydrographer	Gage Height	Discharge	Remarks
April 27, 1901	A. L. Fellows	3.70	1,813	
May 14, 1901	J. E. Field	1.23	74	
June 21, 1901	J. E. Field	4.20	2,530	
Jan. 3, 1902	J. E. Field	2.65	634	
Feb. 28, 1902	J. E Field	2.70	700	
April 2, 1902	J. E. Field	1.85	328	
Aug. 15, 1902	J. E. Field	1.30	62	
Nov. 2, 1902	R. W. Hawley	1.65	188	

*Station established April 27, 1901, by A. L. Fellows, at wagon bridge one and one-half miles north of Kersey.

ESTIMATED DISCHARGE.

Month	Discharge in Second-Feet			Total in Acre-Feet	Run-off	
	Maximum	Minimum	Mean		Second-Feet per Square Mile	Depth in Inches
1901						
May	5,856	62	1,393	86,652	.15	.17
June	5,004	450	1,820	108,297	.19	.21
July	450	290	314	19,307	.03	.03
August	330	290	296	18,200	.03	.03
September	705	290	395	23,504	.04	.04
October	516	370	456	28,038	.05	.05
November	591	450	526	31,299	.06	.07
December	1,955	540	903	55,523	.10	.11
1902						
January	1,524	580	836	51,404	.09	.10
February	1,524	637	862	47,873	.09	.09
March	700	282	486	29,883	.05	.06
April	262	42	122	7,259	.01	.01
May	224	42	96	5,903	.01	.01
June	1,891	80	158	9,402	.02	.02
July	580	80	124	7,625	.01	.01
August	105	80	85	5,226	.01	.01
September	2,631	80	363	21,600	.04	.04
October	325	170	249	15,310	.03	.03
November	527	224	326	18,752	.03	(1) .03

(1) For twenty-nine days.

JULESBURG STATION, ON SOUTH PLATTE RIVER.*

Drainage area, 20,598 square miles.
Observer, Lloyd Jenkins.

LIST OF DISCHARGE MEASUREMENTS.

Date	Hydrographer	Gage Height	Discharge	Remarks
April 2, 1902	J. E. Field	1.30	35	
Oct. 10, 1902	S. G. Lees	1.58	133	
Nov. 8, 1902	R. W. Hawley	1.15	31	

*Established April 2, 1902, by John E. Field, deputy state engineer, at wagon bridge one mile southeast of the railway station at Julesburg.

ESTIMATED DISCHARGE.

Month	Discharge in Second-Feet			Total in Acre-Feet	Run-off	
	Maximum	Minimum	Mean		Second-Feet per Square Mile	Depth in Inches
1902						
April	89	35	46	2,737	.002	.002
May	52	23	37	2,275	.002	.002
June	144	9	28	1 666	.001	.001
July	225	2	19	1,168	.001	.001
August	4	0	3	184	.0001	.0001
September	662	2	153	9,104	.008	.009
October	662	28	129	7,932	.006	.007
November (1)	75	28	35	2,083	.002	(1) .002

(1) For twenty-nine days.

MORRISON STATION, ON BEAR CREEK.*

Drainage area, 170 square miles.
Observer, Samuel Hebrew.

LIST OF DISCHARGE MEASUREMENTS.

Date	Hydrographer	Gage Height	Discharge	Remarks
May 10, 1901	A. L. Fellows	4.60		..... Results good

*As described on page 266, Tenth Biennial Report. No record for 1902.

ESTIMATED DISCHARGE.

Month	Discharge in Second-Feet			Total in Acre-Feet	Run-off	
	Maximum	Minimum	Mean		Second-Feet per Square Mile	Depth in Inches
1901						
April	132	11	54	3.213	.32	.36
May	168	93	116	7,133	.68	.78
June	187	93	114	6,783	.67	.74
July	93	24	52	3,197	.31	.36
August	126	18	40	2,460	.24	.28
September	48	13	22	1.309	.13	.14
October	28	13	19	1,168	.11	.13
November	20	9	15	893	.09	.10
December 1-7	21	14	17	(1) 236	.10	(1) .03

(1) For seven days.

FORKS CREEK STATION, ON CLEAR CREEK.*

Drainage area, 345 square miles.
Observer, C. A. Jones.

LIST OF DISCHARGE MEASUREMENTS.

Date	Hydrographer	Gage Height	Dis-charge	Remarks
May 8, 1901	A. L. Fellows	2.25	231	
June 14, 1902	S. G. Lees	2.90	655	
Sept. 10, 1902	M. C. Hinderlider	1.50	60	
Sept. 20, 1902	M. C. Hinderlider	1.60	55	
Oct. 15, 1902	S. G. Lees	1.80	82	

*As described on page 270, Tenth Biennial Report.

ESTIMATED DISCHARGE.

Month	Discharge in Second-Feet			Total in Acre-Feet	Run-off	
	Maxi-mum	Mini-mum	Mean		Second-Feet per Square Mile	Depth in Inches
1901						
May	860	207	358	34,310	1.62	1.87
June	775	545	653	38,856	1.89	2.11
July	692	235	433	26,624	1.26	1.45
August	367	156	228	24,019	.66	.76
September	179	66	114	6,783	.33	.37
October	93	58	73	4,489	.21	.24
November	58	20	37	2,202	.11	.12
1902						
April	140	55	76	(1) 1,658	.22	(1) .09
May	703	155	450	27,669	1.30	1.50
June	1,079	402	644	38,321	1.86	2.08
July	402	126	224	13,773	.65	.75
August	103	55	86	5,288	.25	.29
September	140	42	64	3,808	.19	.21
October	84	42	65	3,739	.19	.20

(1) Eleven days.

MARSHALL STATION, ON SOUTH BOULDER CREEK.*

Drainage area, 125 square miles.
Observer, Miss Dollie Barber.

LIST OF DISCHARGE MEASUREMENTS.

Date	Hydrographer	Gage Height	Discharge	Remarks
May 3, 1901	J. E. Field	2.00	128	

*As described on page 273, Tenth Biennial Report.

ESTIMATED DISCHARGE.

Month	Discharge in Second-Feet			Total in Acre-Feet	Run-off	
	Maximum	Minimum	Mean		Second-Feet per Square Mile	Depth in Inches
1901						
April	119	7	47	2,797	.38	.42
May	263	64	129	7,932	1.03	1.19
June	278	193	229	13,626	1.83	2.04
July	220	57	118	7,256	.94	1.08
August	78	34	48	2,951	.38	.44
September	34	13	20	1,190	.16	.18

BOULDER STATION, ON BOULDER CREEK.*

Drainage area, 179 square miles.
Observer, Mrs. Carrie Osgood.

LIST OF DISCHARGE MEASUREMENTS.

Date	Hydrographer	Gage Height	Discharge	Remarks
May 2, 1901	J. E. Field	1.65	244	

*As described on page 277, Tenth Biennial Report.

ESTIMATED DISCHARGE.

Month	Discharge in Second-Feet			Total in Acre-Feet	Run-off	
	Maximum	Minimum	Mean		Second-Feet per Square Mile	Depth in Inches
1901						
April	264	5	75	4,463	.42	.47
May	705	164	388	23,857	1.89	2.18
June	789	390	513	30,526	2.87	3.20
July	508	197	319	19,615	1.78	2.05
August	306	46	114	7,010	.64	.74
September	70	16	35	2,083	.20	.22
October	30	11	15	922	.08	.09
November	13	4	8	476	.05	.06
December	6	1	5	307	.03	.03

LYONS STATION, ON ST. VRAIN CREEK.*

Drainage area, 209 square miles.
Observer, L. H. Dickson.

LIST OF DISCHARGE MEASUREMENTS.

Date	Hydrographer	Gage Height	Discharge	Remarks
May 2, 1901	J. E. Field	3.20	278	
July 28, 1902	J. E. Field	2.50	91	
Aug. 30, 1902	J. E. Field	2.05	31	
Nov. 8, 1902	M. C. Hinderlider	2.08	40	Made by wading

*As described on page 280, Tenth Biennial Report, but including discharge of supply ditch.

ESTIMATED DISCHARGE.

Month	Discharge in Second-Feet			Total in Acre-Feet	Run-off	
	Maximum	Minimum	Mean		Second-Feet per Square Mile	Depth in Inches
1901						
April	302	5	114	6,783	.55	.61
May	802	197	421	25,886	2.01	2.32
June	800	363	575	34,215	2.75	3.07
July	574	209	334	20,537	1.60	1.84
August	308	106	177	10,883	.85	.98
September	141	33	70	4,165	.33	.37
October	49	33	39	2,398	.19	.22
November	34	12	24	1,428	.11	.12
1902						
April	57	12	34	2,023	.16	.18
May	500	70	215	13,320	1.03	1.19
June	485	152	312	18,565	1.49	1.66
July	167	69	112	6,887	.53	.61
August	86	43	59	3,628	.28	.32
September	329	31	74	4,403	.35	.39
October	107	42	70	4,304	.33	.38

ARKINS STATION, ON BIG THOMPSON CREEK.*

Drainage area, 305 square miles.
Observer, E. G. McKinney.

LIST OF DISCHARGE MEASUREMENTS.

Date	Hydrographer	Gage Height	Discharge	Remarks
May 1, 1901	J. E. Field	1.30	226	
Aug. 30, 1902	J. E. Field	.75	86	
Nov. 14, 1902	M. C. Hinderlider	.42	28	Made by wading

*As described on page 285, Tenth Biennial Report, but including discharge of Handy ditch.

ESTIMATED DISCHARGE.

Month	Discharge in Second Feet			Total in Acre-Feet	Run-off	
	Maximum	Minimum	Mean		Second-Feet per Square Mile	Depth in Inches
1901						
May	977	208	600	36,893	1.97	2.27
June	1,143	616	859	51,114	2.82	3.15
July	975	255	531	32,650	1.74	2.01
August	506	140	261	16,048	.86	.99
September	110	44	72	4,284	.24	.27
1902						
April	35	20	29	1,726	.10	.11
May	659	80	331	20,352	1.09	1.26
June	773	342	508	30,228	1.67	1.86
July	385	108	181	11,129	.59	.68
August	130	67	90	5,534	.30	.35
September	238	34	90	5,355	.30	.33
October	198	46	98	6,026	.32	.37

FORT COLLINS STATION, ON CACHE A LA POUDRE RIVER.*

Drainage area, 1,060 square miles.
In charge of Prof. L. G. Carpenter.

ESTIMATED DISCHARGE.

Month	Discharge in Second-Feet			Total in Acre-Feet	Run-off	
	Maximum	Minimum	Mean		Second-Feet per Square Mile	Depth in Inches
1901						
May	5,100	619	1,757	108,034	1.66	1.91
June	2,449	1,425	1,956	116,390	1.85	2.06
July	1,455	406	885	(1) 42,129	.83	(1) .74
August	510	242	337	20,721	.32	.37
September	294	98	152	9,045	.14	.16
October	136	93	119	(2) 3,540	.11	(2) .06
1902						
June	1,721	706	1,042	62,003	.98	(3) .73
July	626	241	411	25,271	.39	.45
August	232	109	171	10,514	.16	.18
September	510	74	166	9,878	.16	.18
October	202	124	157	9,654	.15	(4) .12

(1) For twenty-four days.
(2) For fifteen days.
(3) For twenty days.
(4) For twenty-one days.

*As described on page 288, Tenth Biennial Report. By courtesy of Prof. L. G. Carpenter, of the State Agricultural College at Fort Collins, Colorado.

MISCELLANEOUS DISCHARGE MEASUREMENTS IN SOUTH PLATTE IRRIGATION DIVISION.

Stream	Location	Hydrographer	Date	Discharge
1901				
Cache a la Poudre	Greeley	J. E. Field	May 14	50
1902				
Bear Creek	Morrison	W. P. Edwards	July 8	18
North Turkey creek	Near Conifer	W. P. Edwards	July 9	3
Elk creek	Winston	W. P. Edwards	July 9	5
Deer Park creek	Bailey	W. P. Edwards	July 9	4
North Fork S. Platte river	Bailey	W. P. Edwards	July 9	70
Hall's gulch	Webster	W. P. Edwards	July 10	14
Jefferson creek	Jefferson	W. P. Edwards	July 10	16
Michigan creek	Como	W. P. Edwards	July 10	6
Tarryall creek	Near Como	W. P. Edwards	July 10	11
Middle Fork S. Platte river	Fairplay	W. P. Edwards	July 10	39
Four-Mile creek	Near Fairplay	W. P. Edwards	July 11	4
South Fork S. Platte river	Near Buffalo Springs	W. P. Edwards	July 11	28

Note—See also seepage measurements for special gagings.

ARKANSAS IRRIGATION DIVISION.*

TWIN LAKES STATION, ON LAKE CREEK.**

Drainage area, 109 square miles.
Observer, John J. Hartman.

LIST OF DISCHARGES.

Date	Hydrographer	Gage Height	Discharge	Remarks
1901				
May 11	C. W. Beach	.67	99	Interlaken station
May 6	J. E. Field	.50	113	Interlaken station
May 6	J. E. Field	2.00	120	Lower station
May 7	J. E. Field	1.10	42	Lower station
May 7	J. E. Field	1.70	87	Lower station
1902				
April 4			31	Intake or natural flow
May 5			150	Intake or natural flow
May 10			83	Intake or natural flow
May 15 to 19, inclusive			317	Intake or natural flow
July 3			102	Intake or natural flow
July 18 to 23, inclusive			8	Intake or natural flow
July 23 to 30, inclusive			6	Intake or natural flow
July 30 to Aug. 5, inclusive			5	Intake or natural flow
Aug. 5 to Nov. 24, inclusive			5	Intake or natural flow

Note—There were no measurements made in 1902. The above results for 1902 give the in-flow to the lakes or the natural flow in Lake creek on those dates, this being the only available data for this year.

*See page 291, Tenth Biennial Report.

**At station below both lakes, as established by John E. Field, deputy state engineer. By courtesy of The Twin Lakes Land and Water Company. See page 293, Tenth Biennial Report.

SALIDA STATION, ON ARKANSAS RIVER.*

Drainage area, 1,160 square miles.
Observer, William Furniss.

LIST OF DISCHARGE MEASUREMENTS.

Date	Hydrographer	Gage Height	Discharge	Remarks
1901				
April 17......	J. E. Field...........	.40	221	
Sept. 11......	A. L. Fellows	.55	422	
May 10......	C. W. Beach........	1.23	734	
May 7......	J. E. Field...........	1.20	566	Measurements all made from suspension foot bridge back of D. & R. G. R. R. yards.
1902				
April 11......	J. E. Field...........	.55	273	New gage placed on site of old one on Aug. 26, 1902.
April 12......	J. E. Field...........	.55	286	Difference between old and new gage rods 1.1 feet, when old rod read .2 feet.
May 5......	J. E. Field...........	1.40	706	
May 12......	M. C. Hinderlider..	2.20	1,804	
May 19......	J. E. Field....... ..	1.80	1,144	
July 26......	M. C. Hinderlider..	.30	224	
Aug. 27......	M. C. Hinderlider..	1.20	322	

*As described on page 298, Tenth Biennial Report.

ESTIMATED DISCHARGE.

Month	Discharge in Second-Feet			Total in Acre-Feet	Run-off	
	Maximum	Minimum	Mean		Second-Feet per Square Mile	Depth in Inches
1901						
April	926	224	375	22,314	.32	.36
May	4,790	525	1,625	99,917	1.40	1.61
June	2,261	825	1,425	84,793	1.23	1.37
July	1,408	200	492	30,252	.42	.48
August	741	307	424	26,071	.37	.43
September	399	200	259	15,412	.22	.24
October	249	177	219	13,466	.19	.22
November	249	200	216	12,853	.19	.21
1902						
April	293	190	219	13,031	.19	.21
May	1,615	336	852	52,387	.73	.84
June	798	268	467	27,788	.40	.45
July	353	190	229	14,081	.20	.23
August	293	190	217	13,343	.19	.22
September	206	140	168	9,997	.14	.16
October	190	150	174	10,699	.15	.17

CANON CITY STATION, ON ARKANSAS RIVER.*

Drainage area, 3,060 square miles.
Observer, G. A. Prentiss.

LIST OF DISCHARGE MEASUREMENTS.

Date	Hydrographer	Gage Height	Discharge	Remarks
April 17, 1901	J. E. Field	2.50	335	Results questionable
May 7, 1901	J. E. Field	2.85	552	
Sept. 12, 1901	A. L. Fellows	2.30	350	A new gage was placed on Aug. 26, 1902. New gage read 2.30 feet when old gage read 2 feet.
April 21, 1902	J. E. Field	2.20	323	
July 26, 1902	M. C. Hinderlider	1.60	165	
Aug. 26, 1902	M. C. Hinderlider	2.00	226	

*As described on page 300, Tenth Biennial Report.

ESTIMATED DISCHARGE.

Month	Discharge in Second-Feet			Total in Acre-Feet	Run-off	
	Maximum	Minimum	Mean		Second-Feet per Square Mile	Depth in Inches
1901						
January	328	297	305	18,754	.10	.12
February	328	268	283	15,717	.09	.09
March	268	194	214	13,158	.07	.08
April	660	217	373	22,195	.12	.13
May	3,799	442	1,680	103,299	.55	.63
June	2,633	1,690	2,182	129,838	.71	.79
July	1,912	407	795	48,883	.26	.30
August	1,967	407	630	38,737	.21	.24
September	715	270	352	20,945	.12	.13
October	377	270	313	19,246	.10	.12
November	296	270	281	16,721	.09	.10
December	350	296	314	19,307	.10	.12
Total	3,799	194	643	466,800	.21	2.85
1902						
January	331	303	317	19,492	.10	.12
February	331	303	325	18,050	.11	.11
March	360	331	337	20,721	.11	.13
April	393	224	294	17,494	.10	.11
May	1,286	345	757	46,546	.25	.29
June	681	264	481	28,622	.15	.17
July	360	128	229	14,081	.07	.08
August	647	161	270	16,602	.09	.10
September	303	228	254	15,114	.08	.09
October	345	277	313	19,246	.10	.12
November	331	277	294	17,494	.10	.11

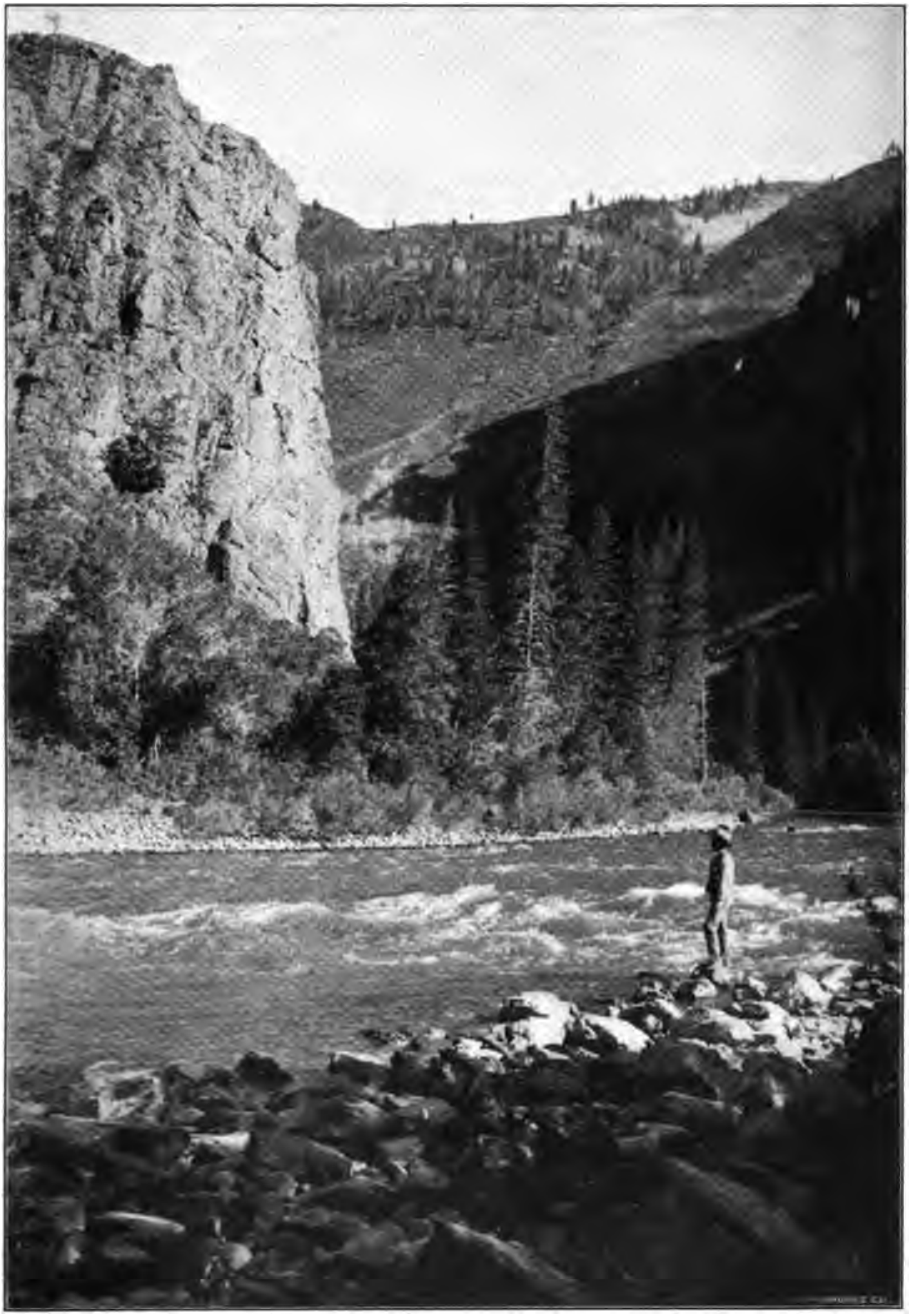
PUEBLO STATION, ON ARKANSAS RIVER.*

Drainage area, 4,600 square miles.
Observer, T. J. Burrows.

LIST OF DISCHARGE MEASUREMENTS.

Date	Hydrographer	Gage Height	Discharge	Remarks
April 14, 1901	J. E. Field	2.00	335	From Main street bridge
May 4, 1901	A. L. Fellows	2.97	1,161	
May 9, 1901	A. L. Fellows	2.30	595	
May 24, 1901	C. W. Beach	3.90	2,204	
May 24, 1901	J. E. Field	4.00	1,946	
June 11, 1901	J. E. Field	4.10	2,382	
July 5, 1901	C. W. Beach	3.02	1,206	
Aug. 26, 1901	C. W. Beach	2.25	603	
Nov. 1, 1901	C. W. Beach	1.70	308	
April 25, 1902	J. E. Field	1.80	220	
May 18, 1902	C. W. Beach	3.10	1,323	
July 7, 1902	C. W. Beach	1.80	193	
July 15, 1902	J. E. Field	1.60	130	
Aug. 24, 1902	M. C. Hinderlider	2.20	358	From Main street bridge
Sept. 1, 1902	C. W. Beach	2.17	341	
Sept. 21, 1902	C. W. Beach	2.05	212	

*As described on page 304, Tenth Biennial Report.



SCENE IN CANON OF GUNNISON RIVER.

ESTIMATED DISCHARGE.

Month	Discharge in Second-Feet			Total in Acre-Feet	Run-off	
	Maxi-mum	Mini-mum	Mean		Second-Feet per Square Mile	Depth in Inches
1901						
January	625	430	474	29,145	.10	.12
February	430	254	414	23,092	.09	.09
March	380	254	322	19,799	.07	.08
April	932	234	551	32,787	.12	.13
May	4.235	625	1,784	109,694	.39	.42
June	4,326	1,650	2,347	139,656	.51	.57
July	2,662	338	1,005	61,795	.22	.25
August	1,500	430	776	47,714	.17	.20
September	1,367	214	429	25,527	.09	.10
October	430	254	320	19,676	.07	.08
November	430	254	328	19,517	.07	.08
December	698	296	445	27,362	.10	.11
Total	4,326	214	766	555,764	.17	2.23
1902						
January	310	190	252	15,495	.05	.06
February	2,175	103	899	49,928	.20	.20
March	225	129	184	11,314	.04	.04
April	225	129	165	9,818	.04	.04
May	1,205	190	706	43,410	.15	.17
June	625	158	415	24,694	.09	.10
July	1,148	60	263	16,171	.06	.07
August	8.321	60	608	37.385	.13	.15
September	388	225	271	16,126	.06	.07
October	360	265	311	19,123	.07	.08
November	417	265	301	17,911	.07	.08

NEPESTA STATION, ON ARKANSAS RIVER.*

Drainage area, 9,130 square miles.
Observer, Z. Swallow.

LIST OF DISCHARGE MEASUREMENTS.

Date	Hydrographer	Gage Height	Discharge	Remarks
May 1, 1901	A. L. Fellows	.97	672	Gage at dam
May 17, 1901	C. W. Beach	1.24	1,719	Gage at bridge
June 7, 1901	J. E. Field	2.25	3,537	Gage at bridge
Aug. 20, 1901	C. W. Beach	.83	438	Gage at bridge
May 23, 1902	C. W. Beach	.60	234	Gage at bridge
June 28, 1902	C. W. Beach	.50	127	Gage at bridge

*As established May 1, 1901, by A. L. Fellows, resident hydrographer, at Oxford Farmers' Canal dam.

ESTIMATED DISCHARGE.

Month	Discharge in Second-Feet			Total in Acre-Feet	Run-off	
	Maximum	Minimum	Mean		Second-Feet per Square Mile	Depth in Inches
1901						
May	3,989	250	1,570	96,536	.17	.20
June	9,200	1,842	3,021	179,762	.33	.37
July	2,068	176	639	39,291	.07	.08
August	3,243	176	719	44,210	.08	.09
September	3,243	142	316	18,803	.03	.03
1902						
April	244	0	119	7,081	.01	.01
May	4,409	0	936	57,552	.10	.12
June	2,352	28	566	33,679	.06	.07
July	2,727	0	312	19,184	.03	.03
August	9,208	0	643	39,537	.07	.08
September	348	0	87	5,177	.01	.01
October	211	108	129	7,932	.01	.01

ROCKY FORD STATION, ON ARKANSAS RIVER.*

Drainage area, 11,440 square miles.
Observer, F. Choppell.

LIST OF DISCHARGE MEASUREMENTS.

Date	Hydrographer	Gage Height	Discharge	Remarks
April 22, 1901	R. W. Hawley	1.60	327	
May 13, 1901	R. W. Hawley	1.75	463	
June 8, 1901	J. E. Field	3.00	2,424	
Sept. 17, 1902	J. E. Field	—.25	25	

*As established April 19, 1901, by R. W. Hawley, at Rocky Ford Crossing. Gage heights furnished by courtesy of American Beet Sugar Company.

ESTIMATED DISCHARGE.

Month	Discharge in Second-Feet			Total in Acre-Feet	Run-off	
	Maximum	Minimum	Mean		Second-Feet per Square Mile	Depth in Inches
1901						
April	1,848	420	981	(1) 58,374	.09	(1) .05
May	4,620	258	1,408	86,575	.12	.14
June	6,220	616	2,101	125,018	.18	.20
July	1,321	137	448	27,546	.04	.04
August	2,035	181	808	49,682	.07	.08
September	2,424	181	345	20,529	.03	.03
October	735	206	345	21,213	.03	.03
November	616	343	432	25,706	.04	.04
December	735	282	454	27,915	.04	.04
1902						
January	616	282	402	24,718	.04	.04
February	1,848	181	1,051	58,369	.09	.09
March	1,489	510	828	50,912	.07	.08

(1) For fourteen days.

PROWERS STATION, ON ARKANSAS RIVER.*

Drainage area, 19,125 square miles.
Observer, D. L. Birge.

LIST OF DISCHARGE MEASUREMENTS.

Date	Hydrographer	Gage Height	Discharge	Remarks
May 3, 1901	A. L. Fellows	.59	204	Gage by wading
June 9, 1901	J. E. Field	1.35	1,953	Gage at Lamar bridge

*At dam of Colorado and Kansas canal, as described on page 312, Tenth Biennial Report.

ESTIMATED DISCHARGE.

Month	Discharge in Second-Feet			Total in Acre-Feet	Run-off	
	Maximum	Minimum	Mean		Second-Feet per Square Mile	Depth in Inches
1901						
January	120	22	49	3,013	.003	.003
February	90	10	55	3,054	.003	.003
March	50	10	38	2,337	.002	.002
April	50	15	37	2,202	.002	.002
May	3,178	35	552	33,941	.03	.03
June	10,553	120	2,715	161,554	.14	.16
July	436	22	177	10,883	.01	.01
August	3,668	35	504	30,990	.03	.03
September	436	10	90	5,355	.005	.006
October	83	10	35	2,152	.002	.002
November	83	22	48	2,856	.002	.002
December	120	10	44	2,705	.002	.002
Total	10,553	10	362	261,042	.02	.252

MISCELLANEOUS DISCHARGE MEASUREMENTS IN ARKANSAS IRRIGATION DIVISION.

Stream	Location	Hydrographer	Date		Discharge
1901					
Arkansas	Granite	J. E. Field	April	18	124
Arkansas	Ft. Lyons dam	A. L. Fellows	May	3	381
Arkansas	Granite	J. E. Field	May	7	366
Arkansas	Lamar	J. E. Field	June	9	997
Arkansas	Barton	J. E. Field	June	10	1,911
1902					
Trout creek	Newell	W. P. Edwards	July	11	4
Chalk creek	Mt. Princeton	W. P. Edwards	July	12	17

RIO GRANDE IRRIGATION DIVISION.*

DEL NORTE STATION, ON RIO GRANDE.**

Drainage area, 1,400 square miles.
Observer, J. S. Regan.

LIST OF DISCHARGE MEASUREMENTS.

Date	Hydrographer	Gage Height	Discharge	Remarks
Sept. 10, 1901	A. L. Fellows	1.75	470	..................Made by wading
July 8, 1902	A. L. Fellows	1.30	210	..................Made by wading

*See page 321, Tenth Biennial Report.
**As described on page 322, Tenth Biennial Report.

ESTIMATED DISCHARGE.

Month	Discharge in Second-Feet			Total in Acre-Feet	Run-off	
	Maximum	Minimum	Mean		Second-Feet per Square Mile	Depth in Inches
1901						
January	928	796	870	53,494	.62	(a) .71
February	995	845	920	51,094	.66	(a) .68
March	878	270	569	34,986	.41	.47
April	1,669	295	670	39,568	.48	.54
May	4,494	1,483	2,568	157,900	1.83	2.11
June	2,754	1,167	1,787	106,334	1.28	1.43
July	1,063	384	595	36,585	.43	.49
August	660	333	466	28,653	.33	.38
September	895	283	448	26,658	.32	.36
October	308	234	264	16,232	.19	.22
November	308	246	274	16,304	.20	.22
December	450	258	366	12,504	.26	.30
Total	4,494	234	816	580,312	.58	7.91
1902						
January	437	336	381	23,427	.28	.32
February	450	385	412	22,811	.29	.29
March	437	189	438	26,932	.31	.36
April	1,027	265	638	37,964	.45	.50
May	1,787	660	1,169	71,879	.84	.97
June	1,201	210	618	36,774	.44	.49
July	189	112	152	9,346	.12	.14
August	631	69	180	11,068	.13	.15
September	348	112	206	12,258	.15	.17
October	312	169	242	14,880	.17	.20
November	660	200	249	14,817	.18	.20

(a) Probably too high, on account of ice.

COLORADO STATE LINE STATION, ON RIO GRANDE.*

Drainage area, 7,695 square miles.
Observer, Roman Mondragon.

LIST OF DISCHARGE MEASUREMENTS.

Date	Hydrographer	Gage Height	Discharge	Remarks
Sept. 9, 1901	A. L. Fellows	1.20	87	Made by wading
July 9, 1902	A. L. Fellows	.60	6	Made by wading

*Or Cenicero station, as described on page 326, Tenth Biennial Report.

ESTIMATED DISCHARGE.

Month	Discharge in Second-Feet			Total in Acre-Feet	Run-off	
	Maximum	Minimum	Mean		Second-Feet per Square Mile	Depth in Inches
1901						
January	594	594	594	36,524	.08	.09
February	594	414	581	32,267	.08	.08
March	774	107	368	22,627	.05	.05
April	1,044	107	278	16,542	.04	.04
May	2,664	1,224	1,680	103,299	.22	.25
June	1,854	236	1,026	61,051	.13	.14
July	236	22	82	5,042	.01	.01
August	142	31	60	3,689	.01	.01
September	58	43	50	2,975	.01	.01
October	79	43	54	3,320	.01	.01
November	142	43	72	4,284	.01	.01
December	414	142	337	20,721	.04	.04
Total	2,664	22	432	312,341	.07	.074
1902						
January	684	414	521	32,035	.07	.08
February	954	594	758	42,097	.10	.10
March	1,494	185	549	33,757	.07	.08
April	504	185	315	18,754	.04	.04
May	594	142	490	30,129	.06	.07
June	414	22	114	6,783	.01	.01
July	22	22	22	1.353	.003	.003
August	22	6	17	1,045	.002	.002
September	31	14	26	1,547	.003	.003

SAN JUAN IRRIGATION DIVISION.*

IGNACIO STATION, ON LOS PINOS RIVER.**

Drainage area, 450 square miles.
Observer, John Wesch.

LIST OF DISCHARGE MEASUREMENTS.

Date	Hydrographer	Gage Height	Discharge	Remarks
April 17, 1901	A. L. Fellows	3.00	264	Made from bridge
Aug. 5, 1901	A. L. Fellows	2.55	110	Made from bridge
Mar. 27, 1902	A. L. Fellows	2.44	57	Made from bridge
July 11, 1902	A. L. Fellows	2.15	39	Made from bridge

*Page 330, Tenth Biennial Report.
**As described on page 336, Tenth Biennial Report.

ESTIMATED DISCHARGE.

Month	Discharge in Second-Feet			Total in Acre-Feet	Run-off	
	Maximum	Minimum	Mean		Second-Feet per Square Mile	Depth in Inches
1901						
April	1,166	109	452	26,896	1.00	1.11
May	1,569	735	1,026	63,086	2.28	2.63
June	887	645	763	45,402	1.70	1.90
July	555	83	226	13,896	.50	.58
August	825	95	202	12,420	.45	.52
September	585	73	186	(1) 9,592	.41	(1) .40
1902						
April	615	73	312	18,565	.69	.77
May	765	465	577	35,478	1.28	1.48
June	495	208	341	(2) 9,469	.76	(2) .40

(1) For twenty-six days.
(2) For fourteen days.

DURANGO STATION, ON FLORIDA RIVER.*

Drainage area, 136 square miles.
Observer, Mrs. Annie Stewart.

LIST OF DISCHARGE MEASUREMENTS.

Date	Hydrographer	Gage Height	Discharge	Remarks
April 16, 1901	A. L. Fellows	1.48	53	Gage from bridge
July 11, 1902	A. L. Fellows	.80	11	Gage by wading

*As described on page 340, Tenth Biennial Report.

ESTIMATED DISCHARGE.

Month	Discharge in Second-Feet			Total in Acre-Feet	Run-off	
	Maximum	Minimum	Mean		Second-Feet per Square Mile	Depth in Inches
1901						
April	339	21	110	6,545	.81	.90
May	625	235	377	23,181	2.77	3.20
June	326	41	172	10,235	1.26	1.42
1902						
April	287	11	63	3,749	.46	.52
May	313	24	134	8,239	.99	1.14
June	86	9	19	1,131	.14	.16
July	17	9	11	676	.08	.09
August	146	7	21	1,291	.15	.17
September	134	5	23	1,369	.17	.19
October	19	7	13	799	.10	.12

DURANGO STATION, ON ANIMAS RIVER.*

Drainage area, 812 square miles.
Observer, C. G. Graden.

LIST OF DISCHARGE MEASUREMENTS.

Date	Hydrographer	Gage Height	Discharge	Remarks
April 17, 1901	A. L. Fellows......	7.00	404	................Gage from bridge
Aug. 5, 1901	A. L. Fellows......	6.80	381	................Gage from bridge
Mar. 20, 1902	A. L. Fellows......	6.15	148	................Gage from bridge
July 12, 1902	A. L. Fellows......	6.72	302	................Gage from bridge

*As described on page 342, Tenth Biennial Report.

ESTIMATED DISCHARGE.

Month	Discharge in Second-Feet			Total in Acre-Feet	Run-off	
	Maximum	Minimum	Mean		Second-Feet per Square Mile	Depth in Inches
1901						
April	2,715	202	845	50,281	1.04	1.16
1902						
April	1,334	140	445	26,479	.55	.61
May	2,750	717	1,699	104,468	2.09	2.41
June........................	2,300	387	1,179	70,155	1.45	1.62
July	342	206	271	16,663	.33	.38
August	717	160	273	16,786	.34	.39
September	434	182	299	17,792	.37	.41
October	434	206	256	15,741	.32	.37

MANCOS STATION, ON MANCOS RIVER.*

Drainage area, 117 square miles.
Observer, Kate D. Kelley.

LIST OF DISCHARGE MEASUREMENTS.

Date	Hydrographer	Gage Height	Discharge	Remarks
April 13, 1901	A. L. Fellows......	......	49	....
Aug. 8, 1901	A. L. Fellows......	......	17	....

*As described on page 346, Tenth Biennial Report.

GRAND RIVER IRRIGATION DIVISION.*

GLENWOOD SPRINGS STATION, ON GRAND RIVER.**

Drainage area, 5,838 square miles.
Observer, William H. Richardson.

LIST OF DISCHARGE MEASUREMENTS.

Date	Hydrographer	Gage Height	Discharge	Remarks
April 11, 1902	J. E. Field..........	3.87	1,328	....From wagon bridge
July 28, 1902	M. C. Hinderlider..	3.90	1,414	....From wagon bridge
Aug. 28, 1902	M. C. Hinderlider..	3.60	1,079	..............From wagon bridge
Nov. 3, 1902	J. E. Field..........	3.30	842	..............From wagon bridge

*Page 349, Tenth Biennial Report.

**Described on page 350, Tenth Biennial Report. An automatic register was placed in position at this station July 28, 1902, by M. C. Hinderlider, assistant resident hydrographer.

ESTIMATED DISCHARGE.

Month	Discharge in Second-Feet			Total in Acre-Feet	Run-off	
	Maximum	Minimum	Mean		Second-Feet per Square Mile	Depth in Inches
1901						
January	810	540	686	42,181	.12	.14
February	970	625	746	41,431	.13	.13
March	970	727	837	51,465	.14	.16
April	7,100	727	1,888	112,344	.32	.36
May	22,895	6,420	13,800	848,529	2.36	2.72
June	15,660	9,620	12,174	724,404	2.09	2.33
July	10,765	2,090	4,833	297,170	.83	.95
August	3,630	1,350	1,904	117,072	.33	.38
September	1,460	840	1,045	62,182	.18	.20
October	970	870	918	56,446	.16	.18
November	935	810	880	52,364	.15	.17
December	935	625	788	48,452	.14	.16
Total	22,895	540	3,375	2,454,040	.58	7.88
1902						
January	882	600	721	44,332	.12	.14
February	845	600	775	42,991	.13	.14
March	882	710	802	49,313	.14	.16
April	2,772	742	1,419	84,436	.24	.27
May	13,980	3,881	9,825	604,120	1.68	1.94
June	12,140	2,772	7,316	435,332	1.25	1.39
July	2,968	1,266	1,864	99,824	.32	(1) .32

(1) For twenty-seven days.

PALISADES STATION, ON GRAND RIVER.*

Drainage area, 8,546 square miles.
Observer, S. L. Purdy.

LIST OF DISCHARGE MEASUREMENTS.

Date	Hydrographer	Gage Height	Discharge	Remarks
April 9, 1902	J. E. Field	12.3	2,564	From wagon bridge
May 27, 1902	M. C. Hinderlider	16.3	9,778	From wagon bridge
July 30, 1902	M. C. Hinderlider	12.2	1,966	From wagon bridge
Aug. 29, 1902	M. C. Hinderlider	12.0	1,662	From wagon bridge
Oct. 2, 1902	J. H. Matthes	12.15	1,415	From wagon bridge
Oct. 2, 1902	J. H. Matthes	12.20	1,465	From wagon bridge
Oct. 26, 1902	J. H. Matthes	12.20	1,361	From wagon bridge

*As established April 9, 1902, by John E. Field, deputy state engineer, at state bridge above Palisades, Colorado.

ESTIMATED DISCHARGE.

Month	Discharge in Second-Feet			Total in Acre-Feet	Run-off	
	Maximum	Minimum	Mean		Second-Feet per Square Mile	Depth in Inches
April	4,230	1,102	2,230	132,694	.26	.29
May	16,208	5,367	11,800	725,554	1.38	1.59
June	13 584	4,416	8,873	527,980	1.04	1.16
July	4,604	1,839	3,024	185,939	.35	.40
August	2,036	944	1,479	90,941	.17	.20
September	2,190	1,102	1,489	88,602	.17	.19
October	2,113	1,809	1,951	119,963	.23	.26

IOLA STATION, ON GUNNISON RIVER.*

Drainage area, 2,298 square miles.
Observer, A. Pomel and Chester A. Green.

LIST OF DISCHARGE MEASUREMENTS.

Date	Hydrographer	Gage Height	Discharge	Remarks
April 11, 1901	A. L. Fellows	2.16	388	
May 17, 1901	A. L. Fellows	4.80	4,005	
July 29, 1901	A. L. Fellows	2.70	836	
May 30, 1902	M. C. Hinderlider	3.60	1,925	
July 19, 1902	A. L. Fellows	1.90	271	
Sept. 1, 1902	M. C. Hinderlider	2.10	400	

*As described on page 357, Tenth Biennial Report.

ESTIMATED DISCHARGE.

Month	Discharge in Second-Feet			Total in Acre-Feet	Run-off	
	Maximum	Minimum	Mean		Second-Feet per Square Mile	Depth in Inches
1901						
April	2,442	426	910	54,149	.40	.45
May	7,402	2,137	3,756	230,947	1.63	1.88
June	3,686	2,289	2,892	172,086	1.26	1.41
July	2,289	663	1,151	70,772	.50	.58
August	1,118	496	679	41,750	.30	.35
September	663	300	399	23,742	.17	.19
October	426	300	322	19,799	.14	.16
November	361	300	310	18,446	.13	.14
1902						
April	1,205	402	759	45,164	.33	.37
May	2,636	1,005	1,838	113,015	.80	.92
June	2,090	330	997	59,326	.43	.48
July	555	221	269	16,540	.12	.14
August	398	221	273	16,786	.12	.14
September	330	221	244	14,519	.11	.12
October	330	221	312	19,184	.14	.16

WHITEWATER STATION, ON GUNNISON RIVER.*

Drainage area, 7,868 square miles.
Observer, James Page.

LIST OF DISCHARGE MEASUREMENTS.

Date	Hydrographer	Gage Height	Discharge	Remarks
May 21, 1901	A. L. Fellows	7.20	20,176	(a)
April 10, 1902	J. E. Field	4.60	2,176	(b)
May 26, 1902	M. C. Hinderlider	6.10	3,322	
July 31, 1902	M. C. Hinderlider	3.20	384	
Aug. 30, 1902	M. C. Hinderlider	4.60	1,230	
Sept. 20, 1902	G. H Matthes	3.20	302	
Nov. 1, 1902	J. E. Field	3.80	622	

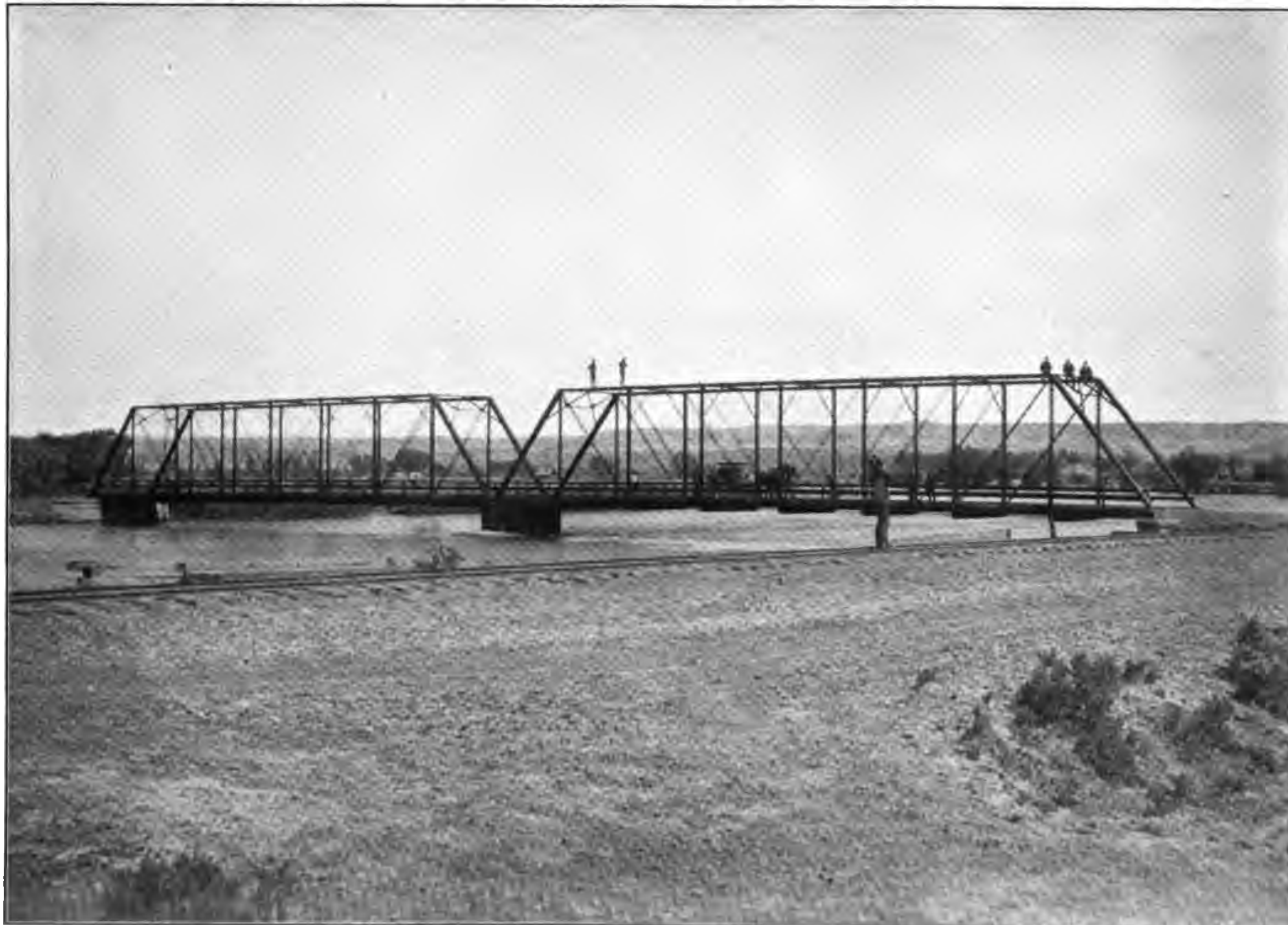
*Established April 10, 1902, by John E. Field, deputy state engineer, at state bridge, one-half mile above Whitewater railroad station.

(a) Gage rod located back of railroad station.

(b) Gage rod at wagon bridge.

ESTIMATED DISCHARGE.

Month	Discharge in Second-Feet			Total in Acre-Feet	Run-off	
	Maximum	Minimum	Mean		Second-Feet per Square Mile	Depth in Inches
1902						
April	2,922	260	1,219	72,535	.16	.18
May	12,271	2,481	7,772	477,885	.99	1.14
June	7,515	623	3,284	195,411	.42	.47
July	1,004	383	570	35,048	.07	.08
August	1,169	341	610	37,507	.08	.09
September	1,461	427	667	39,689	.08	.09
October	860	383	504	30,990	.06	.07



GUNNISON RIVER BRIDGE, MESA COUNTY.

DOLORES STATION, ON DOLORES RIVER.*

Drainage area, 524 square miles.
Observer, Mary D. Smith.

LIST OF DISCHARGE MEASUREMENTS.

Date	Hydrographer	Gage Height	Discharge	Remarks
April 15, 1901	A. L. Fellows.....	3.60	558	................From foot bridge
July 14, 1902	A. L. Fellows......	2.65	47	................From foot bridge

*As described on page 364, Tenth Biennial Report.

ESTIMATED DISCHARGE.

Month	Discharge in Second-Feet			Total in Acre-Feet	Run-off	
	Maximum	Minimum	Mean		Second-Feet per Square Mile	Depth in Inches
1901						
March	412	82	180	11,068	.34	.39
April	2,250	82	873	51,947	1.67	1.86
May	2,731	1,371	2,060	126,664	3.93	4.53
June	1,641	810	1,204	71,643	2.30	2.57
July	628	143	267	16,284	.51	.59
August	313	102	176	10,822	.34	.39
September	193	17	42	2,499	.08	.09
October	37	17	28	1,722	.05	.06
1902						
April	1,157	51	497	29,574	.95	1.05
May	1,323	484	857	52,695	1.64	1.89
June	811	106	342	20,350	.65	.72
July	106	28	56	3,443	.11	.13
August	341	20	92	5,657	.18	.21
September	237	28	62	3,689	.12	.13
October	37	28	34	2,091	.06	.07

MISCELLANEOUS DISCHARGE MEASUREMENTS IN GRAND RIVER IRRIGATION DIVISION.

Stream	Location	Hydrographer	Date	Discharge
1901				
Dolores	Rico	A. L. Fellows	Aug. 9	96
Uncompahgre	Delta	A. L. Fellows	Oct. 21	13
Gunnison	Tongue creek	A. L. Fellows	Oct. 22	605
Surface creek	Cedar Edge	A. L. Fellows	Oct. 23	15
Plateau creek	Colbran	A. L. Fellows	Oct. 24	24
Pass creek	Kremmling	A. L. Fellows	Nov. 13	5
Muddy creek	Kremmling	A. L. Fellows	Nov. 13	12
Blue river	Kremmling	A. L. Fellows	Nov. 13	180
Troublesome	Troublesome	A. L. Fellows	Nov. 13	36
1902				
Lathos creek	At its mouth	W.P.Edwards	July 13	15
Taylor river	Clarke's ranch	W.P.Edwards	July 13	259
Grand river	Near mouth of Piney creek	J. E. Field	Oct. 11	488
Spring creek	Near Gunnison	W.P.Edwards	July 13	19
Cebolla	Between Spencer and Dubois	W.P.Edwards	July 14	67
Lake Fork	Carr's ranch	W.P.Edwards	July 15	171
Pine creek	Near Gate View	W.P.Edwards	July 15	13
Little Blue creek	At mouth	W.P.Edwards	July 15	9
Big Blue creek	Above junction	W.P.Edwards	July 15	18
Little Cimarron creek	At mouth	W.P.Edwards	July 15	16
Cimarron river	At Cimarron	W.P.Edwards	July 15	119

GREEN IRRIGATION DIVISION.*

CRAIG STATION, ON YAMPA RIVER.**

Drainage area, 1,730 square miles.
Observer, H. Jones.

LIST OF DISCHARGE MEASUREMENTS.

Date	Hydrographer	Gage Height	Discharge	Remarks
May 25, 1901	A. L. Fellows	7.10	6,890	From wagon bridge
Nov. 3, 1901	A. L. Fellows	2.20	179	From wagon bridge
July 7, 1902	A. J. McCune	3.05	987	From wagon bridge
Oct. 15, 1902	J. E. Field	2.30	243	From wagon bridge

*Page 370, Tenth Biennial Report.
**Established May 25, 1901, at wagon bridge, one mile south of Craig, Colorado.

ESTIMATED DISCHARGE.

Month	Discharge in Second-Feet			Total in Acre-Feet	Run-off	
	Maximum	Minimum	Mean		Second-Feet per Square Mile	Depth in Inches
1901						
May	7,086	6,285	6,684	(1) 92,803	3.86	(1) 1.01
June	6,285	2,203	4,283	254,856	2.47	2.76
July	1,917	321	745	45,808	.43	.49
August	423	198	301	18,508	.17	.20
September	276	136	190	11,306	.11	.12
October	235	136	181	11,129	.10	.12
1902						
April	4,195	370	1,797	106,929	1.04	1.16
May	8,728	3,320	6,722	413,320	3.89	4.48
June	8,522	825	3,969	236,172	2.29	2.55
July	1,081	198	479	29,452	.28	.32
August	165	90	115	7,071	.07	.08

(1) For seven days.

HAMILTON STATION, ON WILLIAMS RIVER.

This station is located at the Hamilton postoffice, on Williams river, seventeen miles southwest from Craig, Colorado.

No records of gage heights have been kept, but measurements have been made at this point as opportunities were offered. The following measurements have been taken:

LIST OF DISCHARGE MEASUREMENTS.

Date	Hydrographer	Gage Height	Discharge	Remarks
May 25, 1901	A. L. Fellows......	......	1,214	...............Made from bridge
Nov. 3, 1901	A. L. Fellows......	......	43	................Made by wading
July 7, 1902	A. J. McCune......	......	136	................Made by wading
Oct. 16, 1902	J. E. Field..........	......	47	................Made by wading

MEEKER STATION, ON WHITE RIVER.*

Drainage area, 634 square miles.
Observer, L. F. Van Cleave.

LIST OF DISCHARGE MEASUREMENTS.

Date	Hydrographer	Gage Height	Discharge	Remarks
May 24, 1901	A. L. Fellows	5.60	2,605	
Oct. 28, 1901	A. L. Fellows	3.60	397	
July 6, 1902	A. J. McCune	4.00	472	
Oct. 17, 1902	J. E. Field	2.55	342	

*Established May 24, 1901, by A. L. Fellows, resident hydrographer, at wagon bridge one-half mile above town, on ranch of L. F. Van Cleave.

ESTIMATED DISCHARGE.

Month	Discharge in Second-Feet			Total in Acre-Feet	Run-off	
	Maximum	Minimum	Mean		Second-Feet per Square Mile	Depth in Inches
1901						
May	6,084	2,164	3,110	(1) 61,686	4.91	(1) 1.82
June	2,459	667	1,382	82,235	2.18	2.43
July	616	397	454	27,915	.72	.83
August	438	384	407	21,025	.64	.74
September	429	384	392	23,326	.62	.69
October	412	384	394	24,226	.62	.71
1902						
April	616	384	433	25,765	.68	.75
May	3,284	696	1,927	118,487	3.04	3.50
June	2,024	420	843	50,162	1.33	1.48
July	481	360	414	25,456	.65	.75
August	384	360	372	22,873	.59	.68
September	412	372	389	23,147	.61	.68
October	412	384	387	23,796	.61	.70

(1) For ten days.

MISCELLANEOUS DISCHARGE MEASUREMENTS IN GREEN IRRIGATION DIVISION.

Stream	Location	Hydrographer	Date	Discharge
1901				
Milk creek	Near Axial	A. L. Fellows	May 26	188
Milk creek	Near Axial	A. L. Fellows	Oct. 28	4
Elk Head creek	At mouth	A. L. Fellows	Nov. 9	7
Sage creek	At mouth	A. L. Fellows	Nov. 10	3
Fish creek	Dunkley	A. L. Fellows	Nov. 10	5
Trout creek	Pinnacle	A. L. Fellows	Nov. 10	9
Oak creek	Pinnacle	A. L. Fellows	Nov. 11	3
Hunt creek	Near Yampa	A. L. Fellows	Nov. 11	6
Yampa	Yampa	A. L. Fellows	Nov. 12	10
North Fork of Yampa	At Junction	A. L. Fellows	Nov. 12	4
East Fork of Yampa	At Junction	A. L. Fellows	Nov. 12	3
Rock creek	Toponas	A. L. Fellows	Nov. 12	8
Little Rock creek	Toponas	A. L. Fellows	Nov. 12	3
1902				
Snake	Near Dixon	A. L. Fellows	July 10	253
Rock creek	McCoy's ranch	J. E. Field	Oct. 11	11
Yampa	Steamboat Springs	J. E. Field	Oct. 13	112
Yampa	Hayden	J. E. Field	Oct. 14	235
Elk river	Trull	J. E. Field	Oct. 13	147

PRECIPITATION.

Tables of precipitation at the different stations maintained by the Weather Bureau of the U. S. Department of Agriculture are furnished by courtesy of Mr. F. H. Brandenburg, section director. The tables are compiled from the official records as published by him. The annual summaries for the years 1900 and 1901 are given in full, as it is believed that it will prove of general interest throughout the state. The annual summary for the year 1902 being not as yet compiled, is necessarily omitted.

ANNUAL SUMMARY NO. 5.—REVIEW OF THE CROP SEASON OF 1900.

Plowing and seeding were greatly facilitated by the absence of frost in the ground and the ideal weather conditions that obtained during March, which, for the state as a whole, proved to be the warmest and dryest since 1887. In the southern and extreme western counties about one-half the plowing was done and more than average progress was made in the north-central section and on the Divide. At the close of the month a considerable area was seeded to wheat, oats, and barley, and winter wheat and rye were reported in good condition. In the western counties apricots and plums were in full bloom and peaches and pears nearly as far advanced: similar conditions obtained in the southeastern counties. Moisture was generally needed on the ranges and for the germination of crops.

As regards weather conditions, agricultural districts on opposite sides of the Continental Divide had little in common during April.

In the western counties timely showers furnished the necessary moisture without interfering with farming operations, and, despite several cool spells and frosts, vegetation made fair progress and fruit escaped serious injury.

Seeding was practically completed in San Luis Park, and, as more than the usual precipitation was general, conditions were favorable to germination; warmer weather, however, was essential to vigorous growth.

East of the mountains, low temperatures, deficiency of sunshine, and excessive precipitation characterized the month. Fortunately, few varieties of fruit were far enough advanced to be injured by the hard freeze of the 10th-12th.

The ground was saturated to an unusual depth during the opening week and, as intervals of sunshine were few and subsequent precipitation frequent and copious, work was practically at a standstill throughout the month in the North-central section and over the Arkansas-Platte Divide.

The weather conditions during May were favorable. In the districts east of the mountains, seeding and planting were soon completed, germination was rapid and plants made excellent growth during the closing days. Gardens—which up to that time had made only slight advancement—improved rapidly. A good stand of sugar beets was secured in the western counties and the Arkansas Valley, and thinning was in progress during the closing week. The ranges afforded excellent pasturage in the eastern and western border counties throughout the month, and in the intermediate districts during the latter half. The water supply was much in excess of needs east of the mountains, and ample in San Luis Valley and the western counties.

As a whole, the weather during June was highly favorable to agricultural interests. A large volume of water was used for irrigation, but the supply continued ample. Destructive hailstorms occurred in El Paso, Huerfano, and Las Animas counties on the 14th and the northeastern corner of the state during the last decade.

During July, the rainfall was generally insufficient for the needs of growing crops.

Early sown grain ripened rapidly and the harvest of wheat, rye and barley began about the middle of the month. Early corn was in silk and tassel during the last decade; late corn and potatoes, especially the latter, made good growth during the last half of the month; sugar beets made favorable progress; cantaloupes attained normal condition early in the month, and the initial shipment was made from the Arkansas Valley on July 31. Pasturage continued ample except in a few localities, but reports of "range drying rapidly" were numerous at the close of the month. The serious need of water for irrigation was confined to localities in the Rio Grande Valley and late priority ditches in general, but the month closed with the supply limited in all sections and immediate and copious rains essential to the life of many pastures and field crops.

During August the prevailing dry weather facilitated cutting, stacking and thrashing, but in other respects was very unfavorable. Desiccating winds necessitated frequent

irrigation and, as a shortage of water was general even in the older canals, all available reservoirs were drawn upon.

The wheat harvest was nearly completed in San Luis Park and other elevated districts, but many fields were cut for fodder. Corn, in general, suffered less than other crops from the lack of moisture and late potatoes continued in fair to good condition in the North-central section and the western counties—where irrigated. Cool nights were rather unfavorable to tree fruits and cantaloupes, and high winds caused a considerable loss of apples east of the mountains. Moderately heavy rains kept the ranges green until toward the close of the month, in the norteastern counties; elsewhere they were generally in an unsatisfactory condition and in localities practically bare. Stock water was scarce during the last decade.

A prolonged period of droughty weather had left the soil so dry that crops failed to derive full benefit from the favorable conditions that prevailed during September. The rainfall was opportune and generally facilitated plowing and seeding, besides improving the outlook for another crop of alfalfa, which, owing to lack of moisture, had been at a standstill. In general, late corn made satisfactory advancement and a good crop was harvested, while potatoes continued thrifty where water for irrigation was available—parts of the North-central section and the Grand and Uncompahgre Valleys. High winds caused a considerable loss of fruit. At the close of the month the outlook for winter pasturage was good in the northeastern and southeastern counties and over small areas on the western slope. In other sections grass did not attain normal growth; it cured early and being brittle the prospect was unsatisfactory. Stock water continued scarce in the South-central counties, and water for irrigation was insufficient even in a majority of the older canals. Frosts occurred in many localities during the second decade but, as a killing frost did not occur until the closing days, late vegetables and vine crops suffered no serious damage.

Special reports, received at the close of the season and representing 102 communities, show that, despite the excessive moisture during April and pronounced droughty conditions throughout the summer, the season as a whole was a successful one. The majority of the crops, to wit: Fall wheat, corn, first and second crops of alfalfa, native hay, strawberries and other small fruits, cherries, apricots, plums, late apples, early and late peaches, pears, cantaloupes, grapes and

sugar beets yielded considerably better than usual, and spring wheat, rye, barley and early apples very close to the normal. On the other hand, oats and the third and the fourth crop of alfalfa averaged below normal; while early and late potatoes were much below in the vicinity of Greeley—the principal potato growing district—and practically a failure elsewhere.

CLIMATOLOGY.

The mean annual temperature was 47.4°, or 2.2° higher than normal; the next in order of warmth in the past five years was 1896, with a mean of 45.8°. The excess was marked on the eastern slope, in San Luis Park, and the northwestern part of the state, with the greatest, 3.8°, in Routt county. Normal temperature was reported from the southwestern part of the state and a deficiency of nearly a degree was noted in Summit county. For the state as a whole, only two months, April and September, gave a deficiency, 2.4° and 1.4°, respectively. The remaining months were warmer than normal, especially January and March, 6.0° and 5.3°, respectively. The mean for July, the warmest month, was 67.7°, and that for February, the coldest month, was 26.8°; while the mean for January and for December was 29.3°.

The mean annual temperature and the mean of the warmest and the coldest month for each of the subdivisions into which the state falls as a result of diversified topogrophy were:

MEAN TEMPERATURES.

	Annual Mean	Warmest Month	Coldest Month
North-central	49.7	69.8 Aug.	27.1 Feb.
Eastern	52.3	74.8 Aug.	26.6 Feb.
Divide	46.7	67.2 Aug.	28.4 Feb.
Arkansas Valley and Baca county	55.0	75.5 Aug.	32.3 Feb.
South-central	46.7	65.7 Aug.	28.6 Feb.
San Luis Park	44.2	63.5 July	25.2 Dec.
Mountain and Park, east	39.6	58.4 Aug.	21.7 Dec.
Mountain and Park, west	35.9	57.6 July	11.7 Jan.
Southwestern	46.5	67.1 July	26.6 Dec.
Grand and Uncompahgre	51.6	76.3 July	30.0 Dec.
Northwestern	45.8	67.3 July	21.6 Jan.

It will be noted that west of the Continental Divide July was the warmest month, while August was the warmest on the eastern slope.

The highest annual mean was 55.6° at Lamar, and the lowest, 32.4 at Breckenridge. The extreme maximum, 109°, occurred at Delta on July 12 and August 27. Readings of 100° or higher were noted during June, July and August in the eastern counties, the Arkansas Valley, the Grand and Uncompahgre Valley, and the northwestern section. The extreme minimum, 32° below zero, was observed at Walden, in North Park, on February 17 and December 31.

The greatest annual range was 128° at Rangely (extremes 106° and —22°). A range of 126° was observed at Lay, Walden, and Hoehne. The least range, 90°, occurred at Lake Moraine (extremes 76° and —14°). The absolute range for the state was 141°.

The annual precipitation was 14.43 inches, or .46 inch less than normal—the least in five years. For 1896 the average was 15.07; 1897, 19.51; 1898, 15.82; and in 1899, 14.67 inches. There was a decided excess in the eastern part of Larimer county, on Pike's Peak, in Elbert county, and along the eastern border south of Arapahoe county; while a pronounced deficiency occurred in Summit and throughout the western counties. There was also less than the usual amount in San Luis Park, the South-central section, and over areas in Douglas, Logan, Weld, and Larimer counties. In the Northwest section October was the wettest month; elsewhere the greatest precipitation occurred in April.

For the six months, April to September, inclusive, the precipitation was 12.45 inches, or 86 per cent. of the annual. The distribution throughout the period was very uneven. April brought 5.96 inches, or nearly as much as May (1.28), June (1.26), July (1.09), August (.68), and September (1.18) combined.

The following table shows the annual amount for each subdivision, together with the precipitation during the wettest and the dryest month.

AVERAGE PRECIPITATION.

	Annual	Wettest Month	Driest Month
North-central	16.34	8.47 Apr.	.11 Nov.
Eastern	18.77	8.46 Apr.	.04 Oct.
Divide	18.70	9.26 Apr.	.17 Jan.
Arkansas Valley and Baca county	17.19	8.24 Apr.	.05 Jan.
South-central	18.63	5.36 Apr.	.21 Jan.
San Luis Park	7.49	1.86 Apr.	.02 Dec.
Mountain and Park, east	14.61	6.31 Apr.	.20 Jan.
Mountain and Park, west	12.15	3.23 Apr.	.16 July
Southwestern	10.75	3.06 Apr.	.02 July
Grand and Uncompahgre	6.44	1.57 Apr.	.03 July
Northwestern	8.97	1.82 Oct.	.29 July

The greatest amount was 33.46 inches at Lake Moraine, on the slope of Pike's peak, and the least, 3.64 inches at Grand Junction.

The annual snowfall in the different subdivisions averaged as follows: Grand and Uncompahgre valley, 8.0; Arkansas valley, including Baca county, 14.5; Eastern, 27.8; San Luis park, 28.2; Southwestern, 35.1; North-central, 45.3; Northwestern, 53.3; Divide, 60.50; South-central, 83.9; Mountain and Park, eastern slope, 95.0; and Mountain and Park, western slope, 108.2 inches. In the last named section the fall was only one-fifth as much as in 1899, while on the eastern slope, where heavy storms prevailed during April, it was about 90 per cent., as compared with the preceding year.

On an average 183 days, or 50 per cent., were clear; 120, or 33 per cent., partly cloudy; and 62, or 17 per cent., cloudy. The average number of rainy days (days with .01 inch or more precipitation) was 55, the least number, 44, being reported from the southwestern counties, and the greatest number, 68, from the North-central and the South-central section.

The prevailing wind was from the west. The total movement at Cheyenne was 93,554 miles; Denver, 72,511; Pueblo, 58,917, and Grand Junction, 46,880, giving average hourly velocities of 10.7 at Cheyenne, 8.3 at Denver, 6.7 at Pueblo, and 5.4 at Grand Junction.

Relative humidity: Per cent. at 6 a. m. and 6 p. m.—Denver, 58 and 37, respectively; Cheyenne, Wyo., 58 and 41; Pueblo, 64 and 35; Grand Junction, 51 and 28. Fort Collins, at 7 a. m., 74 per cent.; at 7 p. m., 59 per cent.

At Denver the average sunshine for the year was 73 per cent. of the possible, or 3 per cent. more than normal. At Grand Junction it was 75 per cent.; at Cheyenne, Wyo., 67 per cent., and at Pueblo, 80 per cent.

ANNUAL SUMMARY NO. 6—REVIEW OF THE CROP SEASON OF 1901.

At the close of March the consensus of opinion seemed to be that the season was backward, but the soil being generally in good condition nearly one-half of the area to be cultivated had been plowed, some progress made in seeding, and preparations were under way for a large acreage of sugar beets. Winter wheat was in good condition only in the districts where water for irrigation was available last fall. Fruit trees wintered well in nearly all sections, but in the Arkansas valley peaches, plums and cherries suffered somewhat from the severe weather of the opening days of January.

April was characterized by an excess of precipitation and by marked warm and cold spells. During the cold and stormy period of the 9th to 16th work was at a standstill in nearly all districts, but the latter half of the month brought conditions that were exceedingly favorable to farming operations and the advancement of vegetation. Apricots and early varieties of peaches, plums and cherries were injured in localities on the western slope by the frosts of the 17th and 20th; otherwise fruits were in fine condition and gave promise of excellent returns.

In the principal agricultural districts the weather conditions during May were more favorable than usual for seeding, planting, germination and stooling, but hardly ideal for the advancement of corn. The planting of sugar beets was practically finished during the second decade and the thinning and cultivating of early fields begun. Tree fruits set well and, though there were some reports of injury by blight, the outlook remained promising. With the warm weather of the second decade grass made rapid advancement and the ranges soon afforded excellent pasturage, except in the foothill districts. Alfalfa and garden truck were seriously damaged by frosts on the 26th in the northeastern counties, and very destructive hailstorms occurred on the 11th near Hoehne, the 20th-22d in the eastern part of Larimer county, and the 27th-29th at Santa Clara.

The weather conditions during June were in the main favorable, though the first and second decades were rather cool and the last dry and very warm. In general, winter and

spring grains continued thrifty, but many upland field crops failed to germinate or showed the effect of insufficient moisture. The alfalfa crop was secured in excellent condition, except in localities where the harvest was under way during the showery period of the first and second decades. Owing to cool weather, corn, potatoes and gardens were rather backward for a time. Small fruits were plentiful and the outlook for tree fruits remained satisfactory, notwithstanding loss by high winds and "dropping." The ranges afforded excellent pasturage; the need of moisture was evident, however, toward the close of the month. In the northeastern counties frost injured tender vegetation on the 6th, and on the 14th hail and heavy rains caused considerable damage in Boulder, Pueblo, Prowers, Cheyenne and Kit Carson counties.

July was notably dry, with an exceptionally large number of hot days. Where water was available for irrigation a majority of the crops made satisfactory progress, excessive heat at a critical period, however, caused a shrinkage in the yield of spring wheat, oats, barley and millet and a scarcity of water materially reduced the yield of the second cutting of alfalfa. Early sown grains ripened rapidly and the harvest of wheat and oats was under way during the last decade. Upland crops showed the effect of lack of moisture and at the close of the month many fields were past reviving, while the ranges remained brown and in localities stock was fed. In general tree fruits made normal growth, but complaints of "dropping" were numerous during the closing days. In the vicinity of Rocky Ford and La Junta vine crops were badly injured by hail on the 24th.

The next month was one of the wettest Augusts in thirteen years, in sharp contrast with the preceding one which was one of the dryest Julys. The precipitation came too late to restore to good condition all late seedings and plantings, still a number of upland crops which had been given up soon showed improvements and at least gave promise of being valuable for fodder. The moisture improved the outlook for a third crop of alfalfa and was of much benefit to late corn, potatoes and ranges. The shipment of late varieties of tree fruits was begun during the last decade. On the 13th hail seriously damaged grain crops in the upper Rio Grande valley and cantaloupes, melons and sugar beets in Bent and Prowers counties.

The weather conditions during September were favorable to belated crops, harvesting and thrashing, but the soil was rather dry for plowing, seeding and the germination of win-

ter grain. The showers were generally confined to the first decade and were beneficial to ranges, potatoes and the third crop of alfalfa. The maturing of the potato crop was not seriously interrupted by the frosts and digging was general during the last decade. Corn matured rapidly, but a large acreage was cut for fodder. High winds were general on the 24th and caused considerable damage to hay in stack and windrows, besides blowing off many late apples and breaking the trees. A hailstorm on the 6th in Weld county was rather destructive to wheat in shock, potatoes, sugar beets and alfalfa. At the close of the month the ranges as a whole were in satisfactory condition.

During October the weather conditions were ideal for the ripening and gathering of outstanding crops.. Dryness of the soil was a drawback. In the few localities favored with rainfall a large acreage was plowed, but, as a rule, preparation for next year's crops was not as far advanced as usual, even though many fields were irrigated to facilitate the work. Lack of precipitation also materially interfered with seeding and germination. In localities the needed moisture was obtained by irrigation, but over large areas grain was not yet up and the condition of wheat and rye as a whole was below the average. At the close of the month potato digging was still under way and, owing to a decided increase in the acreage and a scarcity of help, more than half of the sugar beet crop was still in the fields.

Notwithstanding the drouth and a scarcity of water during midsummer, in addition to the injury caused by the excessive heat that prevailed during the latter part of June and throughout July, and which irrigation could not entirely counteract, the season, as a whole, proved very satisfactory, for the majority of crops yielded better than usual—the exceptions being apples, early peaches and the third crop of alfalfa.

CLIMATOLOGY—TEMPERATURE.

The mean annual temperature was 47.2°, or 1.4° warmer than normal and practically the same as for 1900, which was the warmest of the past six years. An excess was general on the eastern slope and in the western counties, but in the central part of the state and localities in the eastern foothill region the mean temperatures were normal or slightly below. April gave a deficiency of 1.4°; February, March, June and September were practically normal; while the remaining months brought an excess, especially January,

July, October and November. Comparison with the records, which cover fourteen years, shows only one warmer July (1890) and one warmer October (1900), and that the mean for either August or November has not been equaled. The mean for July, the warmest month, was 71.5°, and for January, the coldest month, 26.7°. February and December were nearly as cold, the means being 27.0° and 27.8°, respectively. The means for the remaining months were as follows: March, 34.7°; April, 44.2°; May, 55.3°; June, 63.0°; August, 68.2°; September, 58.7°; October, 49.5°, and November, 39.8°.

The mean annual temperature and the mean of the warmest and the coldest month for each subdivision into which the state falls as the result of its diversified topography were as follows:

MEAN TEMPERATURES.

	Annual Mean	Warmest Month	Coldest Month
North-central	48.6	74.1 July	24.8 Feb.
Eastern	50.4	78.6 July	23.3 Feb.
Divide	47.6	71.0 July	26.4 Feb.
Arkansas Valley and Baca county	53.8	79.4 July	29.7 Feb.
South-central	46.7	67.6 July	28.9 Feb.
San Luis Park	43.8	64.5 July	24.4 Jan.
Mountain and Park, east	40.3	62.8 July	20.1 Jan.
Mountain and Park, west	36.8	62.0 July	11.8 Jan.
Southwestern	44.6	66.7 July	25.1 Jan.
Grand and Uncompahgre	50.9	76.9 July	26.5 Jan.
Northwestern	44.3	68.6 July	20.5 Jan.

It will be noted that January was the coldest month west of the Continental Divide and in the Rio Grande valley, while February was the coldest on the eastern slope.

The highest annual mean was 55.4° at Lamar, and the lowest 33.1° at Breckenridge. The extreme maximum, 108°, was recorded at Delta on June 29 and Lamar on July 10. Readings of 100° or higher were noted during June, July and August in localities in the northeastern quarter of the state and generally in the valleys of the Arkansas, Uncompahgre and Grand. The extreme minimum, 45° below zero, was observed at Antelope Springs, Mineral county, on January 14.

The greatest annual range was 136° at Holyoke (extremes, 106° and —30°). The least range, 102°, occurred at the station near Long's peak (extremes, 82° and —20°). The absolute range for the state was 153°.

PRECIPITATION.

The annual precipitation was 14.14 inches, or 1.48 less than normal—the least in six years. The average for 1896 was 15.07; 1897, 19.51; 1898, 15.82; 1899, 14.67, and 1900, 14.89 inches.

There was a deficiency at three-fifths of the stations; it was marked in Huerfano, the central part of Las Animas, Otero, Lincoln, Douglas, western Arapahoe, the eastern part of Boulder, Summit and Lake counties, and throughout the southwestern part of the state. An excess, nearly as marked, was noted in the extreme eastern part of Larimer and Arapahoe counties and in Yuma and El Paso.

July and November were the driest covered by the records, while the amount for August was practically the same as in 1897—the wettest, August. By months, the values were: January, 0.56; February, 0.63; March, 1.35; April, 2.21; May, 2.33; June, 1.46; July, 1.07; August, 2.25; September, 0.64; October, 0.59; November, 0.21, and December, 0.84. For the six months, April to September, inclusive, the total was 9.96 inches, or 20 per cent. less than for the corresponding period in 1900.

The annual amount and the wettest and driest month in each subdivision were as follows:

AVERAGE PRECIPITATION.

	Annual	Wettest Month	Driest Month
North-central	15.81	4.12 May	.04 Nov.
Eastern	15.75	3.43 Apr.	T. Nov.
Divide	16.16	3.21 Apr.	.01 Nov.
Arkansas Valley and Baca county	11.91	2.82 May	.02 Nov.
South-central	17.08	5.30 May	.22 Nov.
San Luis Park	10.09	2.00 Aug.	.01 Nov.
Mountain and Park, east	14.07	2.44 Aug.	.28 Nov.
Mountain and Park, west	16.40	2.41 Aug.	.18 Sept.
Southwestern	14.79	2.76 Aug.	.24 Sept.
Grand and Uncompahgre	9.32	1.89 Aug.	.15 Sept.
Northwestern	12.60	1.89 May	.17 Sept.

The greatest amount was 27.32 inches at Lake Moraine, and the least 3.16 inches at Buena Vista.

The annual snowfall in the different subdivisions averaged as follows: Arkansas valley and Baca county, 17.7;

San Luis park, 20.1; Grand and Uncompahgre valley, 30.6; Eastern, 33.4; Divide, 51.2; Northwestern, 63.3; North-central, 64.9; South-central, 78.9; Southwestern, 91.0; Mountain and Park, eastern slope, 91.6; and Mountain and Park, western slope, 138.5 inches.

At Denver the average sunshine for the year was 73 per cent. of the possible, or 3 per cent. more than normal. At Cheyenne the average was 67 per cent., and at Pueblo and Grand Junction, 75 per cent. There was no sunshine on 22 days at Cheyenne, 12 days at Denver, 8 days at Pueblo and 2 days at Grand Junction. Number of days with 90 per cent. or more: Denver, 141; Pueblo, 122; Cheyenne, 130, and Grand Junction, 169. At the last named station 113 days had 100 per cent.

The normal sunshine at Denver (11 years' record) is as follows: January, 73; February, 69; March, 68; April, 69; May, 61; June, 71; July, 68; August, 69; September, 76; October, 76; November, 73, and December, 68 per cent. of the possible.

On an average, 179 days, or 49 per cent., were clear; 119, or 33 per cent., partly cloudy; and 67, or 18 per cent., cloudy. The average number of rainy days (days with 0.01 inch or more precipitation) was 64, the least number, 49, being reported from the Arkansas valley and Baca county, and the greatest number, 84, from Mountain and Park, western slope.

The prevailing wind was from the west. The total movement at Cheyenne was 94,206 miles; Denver, 72,262; Pueblo, 59,885, and Grand Junction, 43,649, giving an average hourly velocity of 10.7 miles at Cheyenne, 8.2 at Denver, 6.8 at Pueblo and 5.0 at Grand Junction.

Relative humidity (per cent at 6 a. m. and 6 p. m.): Denver, 66 and 41, respectively; Cheyenne, Wyo., 66 and 49; Pueblo, 68 and 40, and Grand Junction, 58 and 35.

PRECIPITATION AT STATIONS IN DRAINAGE BASIN OF SOUTH PLATTE RIVER.

BOXELDER, COLO.

YEAR	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Normal	.70	.71	1.36	1.93	3.41	1.64	2.20	2.05	.96	.74	.43	.56	16.69
1896	.53	.06	3.24	1.10	2.53	2.16	1.93	3.05	2.86	.02	.27	.08	17.83
1897	.18	.65	2.75	2.22	3.49	1.59	4.03	4.31	.68	.84	.83	.85	21.42
1898	.70	.22	.58	1.32	5.62	1.66	1.36	1.71	1.36	.47	1.17	.17	16.34
1899	1.27	1.78	1.42	1.06	.52	1.79	2.23	1.46	.13	2.51	.08	.17	14.42
1900	.18	.86	.62	6.70	4.00	.54	2.72	.55	1.55	.00	.00	.21	17.93
1901	.19	.63	1.62	2.96	4.18	1.89	.57	1.66	.49	.46	.13	2.47	17.25

BRECKENRIDGE, COLO.

YEAR	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Normal	2.06	3.51	3.65	3.28	2.37	1.05	2.34	2.16	.88	1.43	2.41	2.75	27.89
1896	1.88	1.89	4.83	.60	1.47	.30	3.10	2.29	2.25	.82	3.87	.73	24.03
1897	2.90	1.99	3.53	4.00	1.54	1.53	1.70	2.27	1.16	1.02	.60	2.25	24.49
1898	.29	.59	1.16	1.53	.46	1.14	2.19	1.59	.38	1.53	4.09	1.34	16.29
1899	4.75	5.08	7.94	1.31	.31	1.52	2.29	1.60	.29	2.54	.58	1.20	29.41
1900	.35	2.48	1.06	4.82	1.68	1.12	.33	.74	.30	.60	.44	.70	14.62
1901	2.36	3.02	2.40	3.12	2.87	1.58	.89	4.94	.08	.78	.90	2.86	25.80

CASTLE ROCK, COLO.

YEAR	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Normal	.54	.81	1.03	2.44	2.41	1.82	2.91	2.47	.73	1.19	.50	.75	17.60
1896	.65	.95	1.80	2.30	1.61	.70	3.67	3.57	2.80	1.62	.32	.45	20.44
1897	.47	1.20	2.50	1.37	(2.41)	3.12	3.59	8.10	.24	2.82	(.50)	1.23	27.55
1898	(.54)	(.81)	.40	1.76	6.48	1.82	4.20	1.49	1.35	1.17	1.00	.99	22.01
1899	.63	.67	.77	1.50	.53	1.10	4.48	2.39	T	1.30	.17	1.16	14.70
1900	.10	.63	.62	7.90	.55	1.80	1.77	.24	.06	.40	.33	.30	14.70
1901	.25	.30	1.04	3.47	1.82	1.35	1.72	3.45	.50	.28	T	.59	14.77

CHEYENNE, WYO.

YEAR	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Normal	.39	.50	.87	1.64	2.24	1.52	1.96	1.46	.94	.68	.35	.35	12.90
1896	.68	.31	2.06	2.08	2.85	1.41	6.35	2.52	2.08	.28	.14	.03	20.79
1897	.27	.57	2.32	.60	3.07	1.60	3.77	1.66	.41	1.03	.68	1.27	17.25
1898	.48	.06	.37	.68	3.72	2.33	1.83	.90	.47	.25	1.58	.36	13.05
1899	1.23	1.63	1.89	.97	1.70	.74	3.38	1.15	.07	1.27	.07	.18	14.18
1900	.15	1.25	.72	7.66	.76	1.01	1.20	.70	2.19	.03	.07	.33	16.09
1901	.13	1.10	1.54	2.97	2.47	1.93	1.34	.83	.75	.31	T	1.62	14.99

PRECIPITATION AT STATIONS IN DRAINAGE BASIN OF SOUTH PLATTE RIVER—*Continued.*

DENVER, COLO.

YEAR	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Normal	.55	.54	.93	2.10	2.56	1.33	1.56	1.33	.83	.87	.63	.66	13.89
1896	.25	.24	1.43	.93	1.27	.89	2.80	.97	1.81	.84	.10	.31	11.84
1897	.58	.82	.90	1.31	3.15	2.16	2.06	1.44	.44	1.64	.24	.63	15.37
1898	.20	.68	.28	1.20	4.88	.94	.67	.96	.28	1.05	.85	.99	12.98
1899	.65	.58	1.10	.75	.15	.47	1.92	1.78	.20	1.01	T	.72	9.33
1900	.13	.55	.63	8.24	.53	1.87	1.30	.05	.87	.83	.37	.42	15.29
1901	.05	.06	.88	1.96	1.18	2.09	.01	1.30	.22	.46	T	.89	9.10

DUMONT, COLO.

YEAR	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Normal	.32	.97	1.39	2.45	3.04	1.60	2.58	2.19	1.14	1.39	.78	.78	18.58
1896	.25	.45	2.48	1.22	1.15	.58	2.18	2.81	2.04	.78	.50	.60	15.01
1897	.45	.55	2.00	1.43	3.75	1.71	2.55	2.59	1.42	3.82	.20	.85	20.82
1898	.10	.90	.65	2.45	3.20	2.60	1.67	2.60	.48	.40	1.89	.82	17.76
1899	.60	1.34	2.40	1.45	.62	.76	3.60	2.00	.60	3.55	.42	.85	18.19
1900	.09	1.21	.76	9.23	1.02	2.33	1.87	.75	1.25	.82	.19	.52	19.54
1901	.45	.79	1.22	2.79	2.78	1.15	(2.58)	(2.19)	(1.14)	(1.39)	(.78)	(.78)	17.97

FORT COLLINS, COLO.

YEAR	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Normal	.61	.58	.96	2.21	2.99	1.61	1.88	1.21	.96	.94	.38	.35	14.68
1896	.43	.08	1.73	1.26	1.68	3.05	3.05	2.20	1.55	.49	.05	.24	15.76
1807	.18	.54	2.15	1.39	2.06	1.69	2.65	1.74	.75	.75	.67	.67	15.24
1898	.14	.08	.50	1.08	3.65	1.37	.50	.98	.50	.82	1.24	.17	11.03
1899	.66	1.04	1.50	1.10	1.01	1.08	4.95	.99	.21	3.23	T	.47	16.19
1900	.25	1.12	1.07	10.56	1.75	.82	1.14	.16	1.92	.24	.07	.11	19.21
1901	.19	.38	1.88	3.62	7.47	2.35	.71	.57	2.25	.36	.02	1.37	21.17

GREELEY, COLO.

YEAR	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Normal	.27	.46	.67	1.94	2.22	1.42	1.79	.96	.56	.79	.55	.29	11.92
1896	.67	.18	.93	1.18	1.42	.46	4.82	2.15	.99	.63	.02	.07	13.52
1897	.06	.61	2.02	.81	3.20	2.47	2.98	1.75	.29	1.11	.40	.38	16.09
1898	.20	.33	.23	(1.94)	5.83	1.69	3.50	.83	.13	.78	.60	.37	16.43
1899	1.14	.69	.71	.70	1.15	.47	2.34	1.04	.30	1.85	T	.40	10.79
1900	.16	.58	.62	6.32	.96	.31	1.28	T	1.07	.11	.04	.16	11.61
1901	.22	.45	.95	2.12	2.38	2.45	.26	.47	1.06	.75	.05	1.06	12.22

PRECIPITATION AT STATIONS IN DRAINAGE BASIN OF SOUTH PLATTE RIVER—*Concluded.*

LAPORTE, COLO.

YEAR	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Normal	.55	.72	1.26	2.11	2.94	1.56	1.61	1.28	1.00	.71	.41	.57	14.71
1896	.60	.30	2.70	1.00	2.25	2.59	2.47	1.40	1.27	.50	.01	.40	15.49
1897	.20	.50	2.15	1.62	3.85	1.80	2.51	1.14	2.05	.60	1.10	.70	17.72
1898	.45	.10	.45	.24	5.00	1.27	.67	1.72	.55	.88	1.90	.40	13.63
1899	.89	1.08	1.81	.80	.88	.71	2.62	.95	.18	3.02	.00	.40	13.34
1900	.34	1.47	.79	10.02	1.84	.59	1.75	1.20	1.53	.25	.05	.23	20.06
1901	.05	.27	1.42	4.28	4.82	2.41	.57	.87	.97	.05	.01	1.51	16.73

LONG'S PEAK, COLO.

YEAR	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Normal	.45	.85	1.74	2.28	1.27	1.47	2.67	1.63	1.06	1.46	.61	.54	16.03
1896	.26	.55	3.17	1.00	1.21	.65	3.60	2.95	1.95	1.05	.37	.15	16.91
1897	.78	1.25	1.96	1.45	1.60	1.50	1.85	1.29	.95	1.41	1.07	.55	15.66
1898	.24	.83	.75	1.73	2.07	2.06	2.94	1.53	.81	.60	1.60	.60	15 76
1899	.54	1.15	3.01	1.18	.38	1.09	4.32	1.73	.11	2.50	.02	.64	16.67
1900	.16	.85	.35	6.34	.60	.80	.51	.17	1.93	1.14	.44	.64	13.93
1901	.69	.47	1.19	1.97	1.78	1.47	.85	2.22	1.59	.95	.18	1.00	14.31

MORAINE, COLO.

YEAR	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Normal	.70	1.42	1.69	2.21	2.66	1.21	2.20	1.81	1.02	1.06	.70	.72	17.40
1896	.53	.22	2.87	1.08	1.62	.49	3.88	2.50	2.74	.75	.30	.30	17.28
1897	.61	1.68	1.86	1.29	2.30	1.79	2.52	2.43	.78	1.16	1.25	1.20	18.87
1898	.50	1.05	1.32	1.44	3.05	1.93	2.19	1.67	.40	.99	1.77	.55	16.86
1899	.77	2.32	2.98	1.39	.45	1.57	3.02	1.32	.15	1.96	.00	.65	16.58
1900	.21	1.11	.30	7.74	1.30	.91	.36	.23	2.19	1.42	.47	.48	16 72
1901	.61	.72	1.06	2.36	3.32	1.52	1.43	2.65	.42	.38	.27	1.15	15.89

SUGAR LOAF, COLO.

YEAR	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Normal	1.01	1.32	3.16	2.62	3.85	2.04	2.97	2.75	1.30	1.52	1.17	1.07	24.78
1896	1.10	.40	3.60	1.60	1.15	1.69	3.56	4.45	1.92	1.40	.30	.20	21.37
1897	.40	2.10	6.30	2.81	(3.85)	3.80	3.65	3.91	1.95	3.85	.80	.70	34.12
1898	.90	.90	.80	3.36	3.95	3.51	2.93	2.78	1.30	1.35	2.17	1.18	25.13
1899	1.20	1.22	5.29	1.59	1.11	.74	2.83	3.98	.60	(1.52)	(1.17)	(1.07)	22.32
1900	(1.01)	(1.32)	(3.16)	(2.62)	(3.85)	.95	1.97	1.12	2.97	.60	.20	.97	20.74
1901	.84	.33	2.17	5.60	3.60	2.20	2.80	4.90	.50	.66	.12	1.40	25.12

RECOMMENDATIONS.

In concluding this report permit me to say that a thorough familiarity with the State Engineer's office of Colorado has convinced me that the co-operation between it and the United States geological survey, as carried on in the past, has been of very great value to both parties and to the state of Colorado. It is very unfortunate, in my opinion, that there is no civil service system in the Colorado state government, as there is in the national. I hope, however, that the state may, at a not distant day, reach such an enlightened condition that it may see the absurdity of changing officials, especially those engaged in scientific pursuits, where only extended practice can make their services most effective. It is only through effort applied constantly and in one direction that great ends are attained. Such advances may be observed in adjacent states, and, more particularly, in the scientific branches which are especially studied by some of the bureaus of the federal government. I recommend, therefore, the passage of a civil service law, applicable to all the scientific departments of the state government, and especially to those having to do with the distribution and use of water. I firmly believe that such a law would be found of such great value that the civil service would soon be extended over at least all clerical positions in all the state offices.

I also suggest the advisability of the state's co-operating more fully with the United States geological survey. Many other states appropriate large amounts for direct co-operation with this survey for the purpose of making geological or hydrographic examinations and surveys of the states immediately interested. The state of Colorado has received much more than its proportion of the sums appropriated for the use of the geological survey by the federal government, and has not done its own duty in assisting so far as it should in this work. The State Engineer's office, particularly, has for many years been handicapped by the fact that it has had insufficient funds to carry on the work delegated to the office to the best possible advantage. The state legislature should, in my opinion, make an appropriation sufficiently large so that this important state department might actually, as well

as nominally, co-operate in this direction. The results attained would, without doubt, be of far greater value to Colorado than they are at the present time. Although detailed surveys of reservoir sites and great irrigation systems are now being made by the United States geological survey, it would be far more creditable to the state of Colorado if it would do its own share in this work, instead of disbursing the money belonging to the internal improvement fund, as is too often done, in places where it can be of no permanent value. I venture to express my hope, therefore, that an appropriation at least equivalent to the entire amount permitted by existing statutes to the State Engineer's office may be appropriated by the state legislature.

I desire once more to urge upon your attention the desirability of the construction of permanent gaging stations. The attention of State Engineers has been repeatedly directed to this matter in preceding years. It would certainly seem that in matters of so great importance to the state as an accurate knowledge of the flow of the South Platte, the Arkansas, the Grand, and its other important streams, its legislature would see the importance of appropriating funds necessary for acquiring such definite information in the most exact way. Appropriations for these stations ought to be made in addition to the regular appropriations to the State Engineer's office, and from the general improvement fund. I know of no possession of the state more important to it than its water supply, and I, therefore, urge most strongly that the appropriations necessary for a thorough knowledge of this most valuable asset be made. At least $5,000 should, in my estimation, be appropriated for this purpose at once. This amount would cover the construction of permanent stations upon any three of the more important streams of the state. This expenditure, however, should be left to the discretion of the State Engineer, so that the best possible locations might be selected, without his being hampered by the requirement that the money be expended at certain designated points, which would probably be of less value than others that could be chosen after careful investigation.

In making these recommendations I am prompted solely by my belief as to what will be best for the state of Colorado. While I feel that much has been accomplished, I feel also that much more could have been done had there been a proper appreciation of the needs of the state and of the importance of the State Engineer's office.

Thanking you once more for the uniform courtesy and the assistance so generously furnished, at the expense of both time and labor, by yourself and your deputy, Mr. John E. Field, I am,

Respectfully yours,

A. L. Fellows,

Resident Hydrographer, U. S. Geological Survey.

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